Progress Report

Study No. 1: Studies to Evaluate Achievement of Freshwater Inflow Standards and Ecological Response

Presented by Dan Opdyke, Ph.D., P.E., and Marty Heaney

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ANCHOR QEA

BIO-WEST

Trungale Engineering & Science

Dr. Tom Soniat, UNO

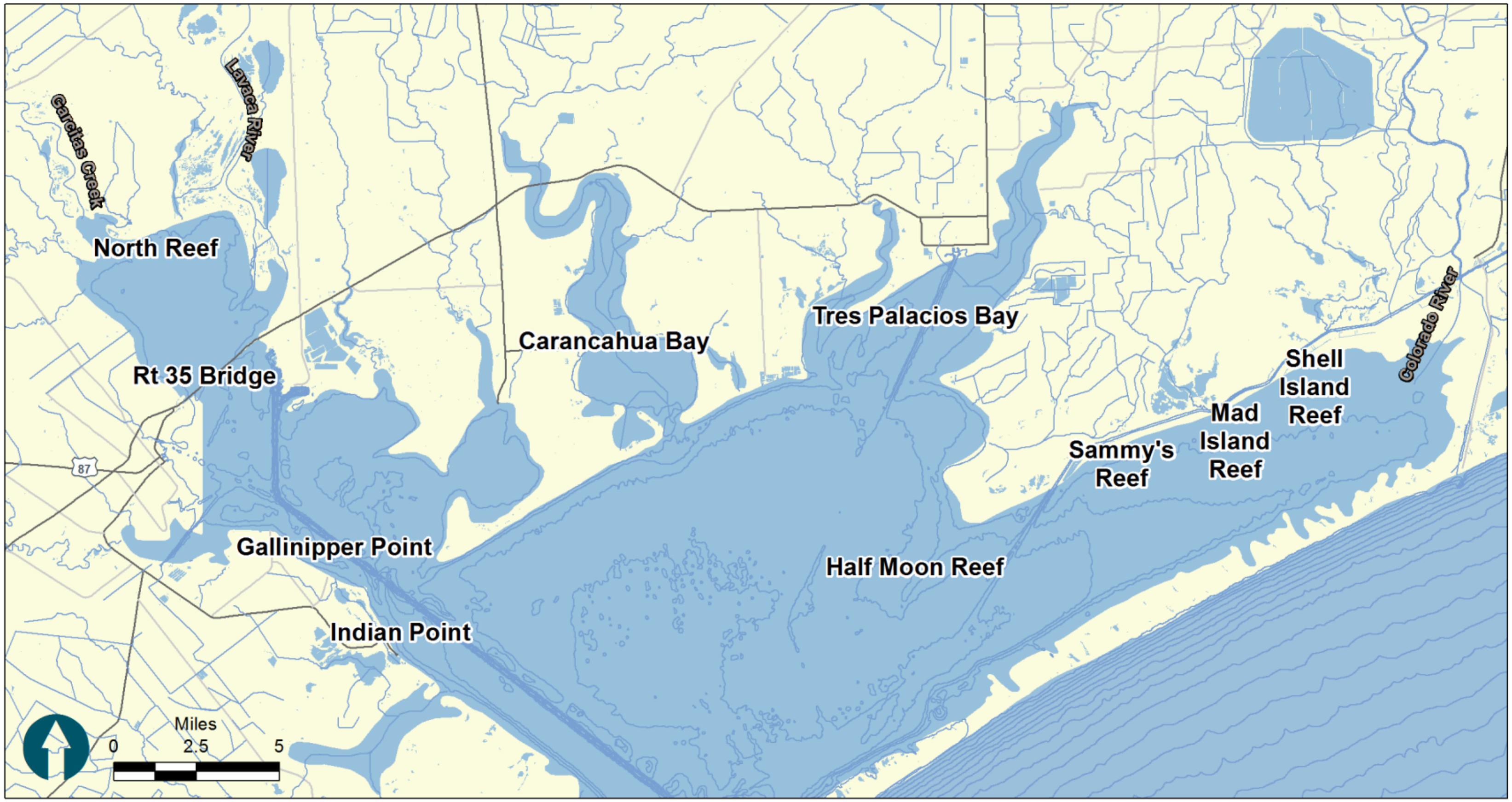
Dr. Bryan Black, UTMSI

Overview

- Background
- Hydrology and Salinity
- Oysters and Dermo
- Marsh Productivity
- Throw Trap
- *Rangia* Clams
- Salinity Modeling
- Next Steps

All results are preliminary and are subject to change

Map of Study Area



Matagorda Bay Health Evaluation Studies

- Matagorda Bay Health Evaluation (MBHE) conducted circa 2004 to 2008
- Component of the LCRA-SAWS Water Project
- Culminated in a final report – December 2008
- Recommended inflow criteria to Matagorda Bay based on multidisciplinary studies

MBHE Studies

	Threshold	MBHE 1	MBHE 2	MBHE 3	MBHE 4	Long-term Volume and Variability
Design Area	Delta	Delta Edge to Mad Island Transect	Delta Edge to Mad Island Transect	Delta Edge to Mad Island Transect	Delta Edge to Mad Island Transect	EAMB
Salinity range across area (ppt)	< 30[1]	27-29	24-26	20-23	15-18	Average[4]
Trophic Level						
Primary Production	Low	Low	Low	Moderate	High	Normal[5]
Oyster Health	Refuge[2]	Refuge[2]	Poor[2]	Fair	Good	Normal[5]
Benthic Condition	Fair / Poor	Poor	Fair	Good	Peak	Normal[5]
Marsh Productivity	Fair	Fair	Good	Good	Good	Normal[5]
Shellfish Habitat	Good[3] / Poor	Good[3] / Poor	Selected[3] / Fair / Poor	Selected[3] / Fair	Selected[3] / Good	Normal[5]
Forage Fish Habitat	Poor / Refuge	Poor / Refuge	Poor	Fair	Good	Normal[5]

To be evaluated in this effort

Source: 2008 MBHE Final Report, Table 11

Review of Existing Standards

- BBEST Report
  - *"The recommended suite of Matagorda Bay Inflow Criteria for the Colorado River … was adopted from the MBHE study"*
  - Lavaca Bay analysis generally followed MBHE science
- BBASC Report
  - *"The Committee agreed to recommend that the BBEST recommended values, with certain limited adjustments, should be included in the environmental flow standards…"*
- Standards (March 9, 2012, TCEQ memo and 30 TAC §298.330(a)(2))
  - *"The proposed … standards for Matagorda and Lavaca Bays generally track the recommendations of the stakeholders."*

BBASC Project Goal

- Corroborate existing inflow standards or suggest new relationships between inflows and ecology
  - Collect field data and extend existing datasets through 2014
  - Incorporate new data since completion of original scientific studies, specifically including data for recent drought conditions
  - Evaluate impacts of recent drought on previously developed relationships between inflows and ecology
  - Expand upon MBHE studies

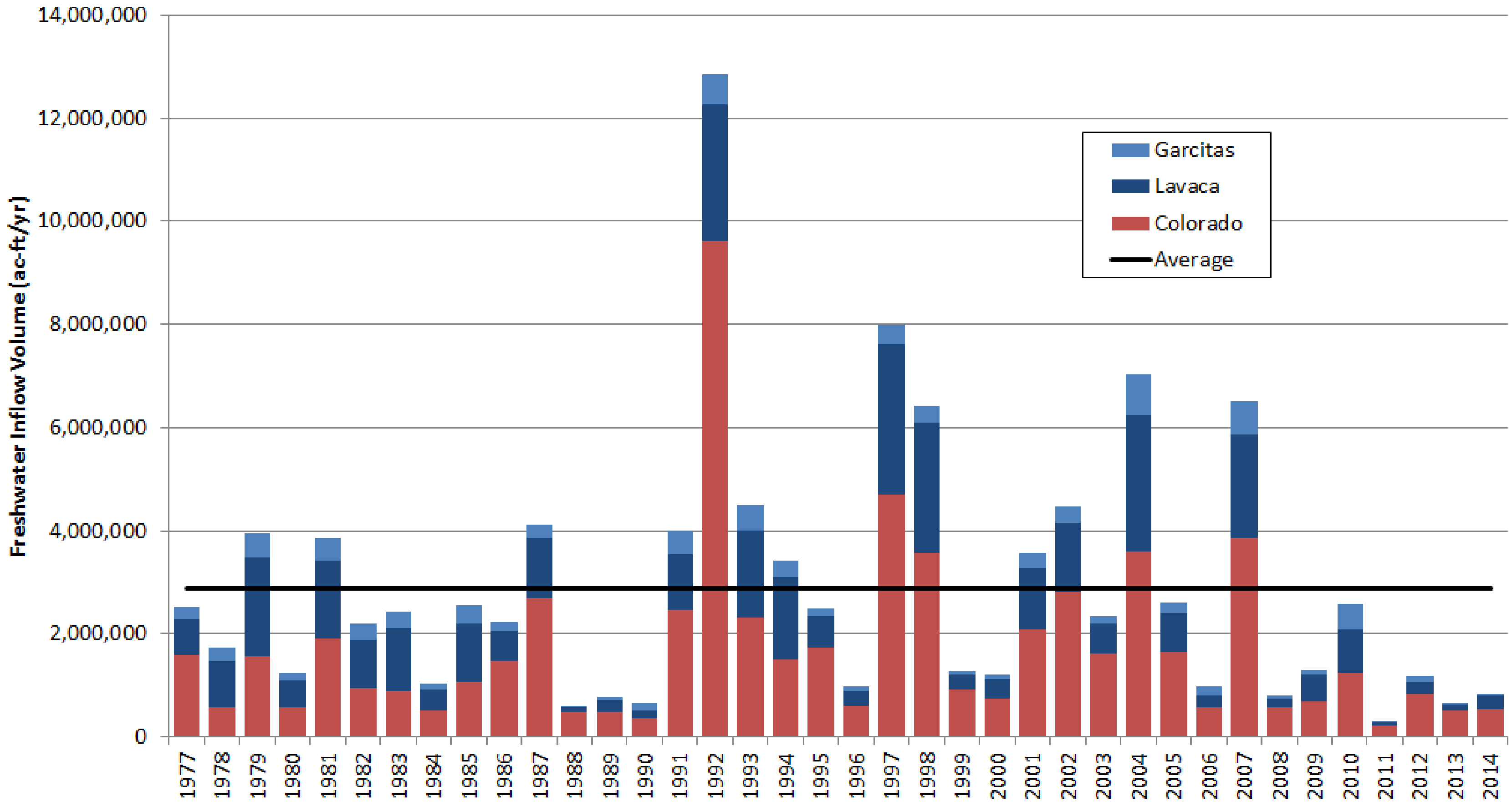
Hydrology and Salinity

Inflow Calculations

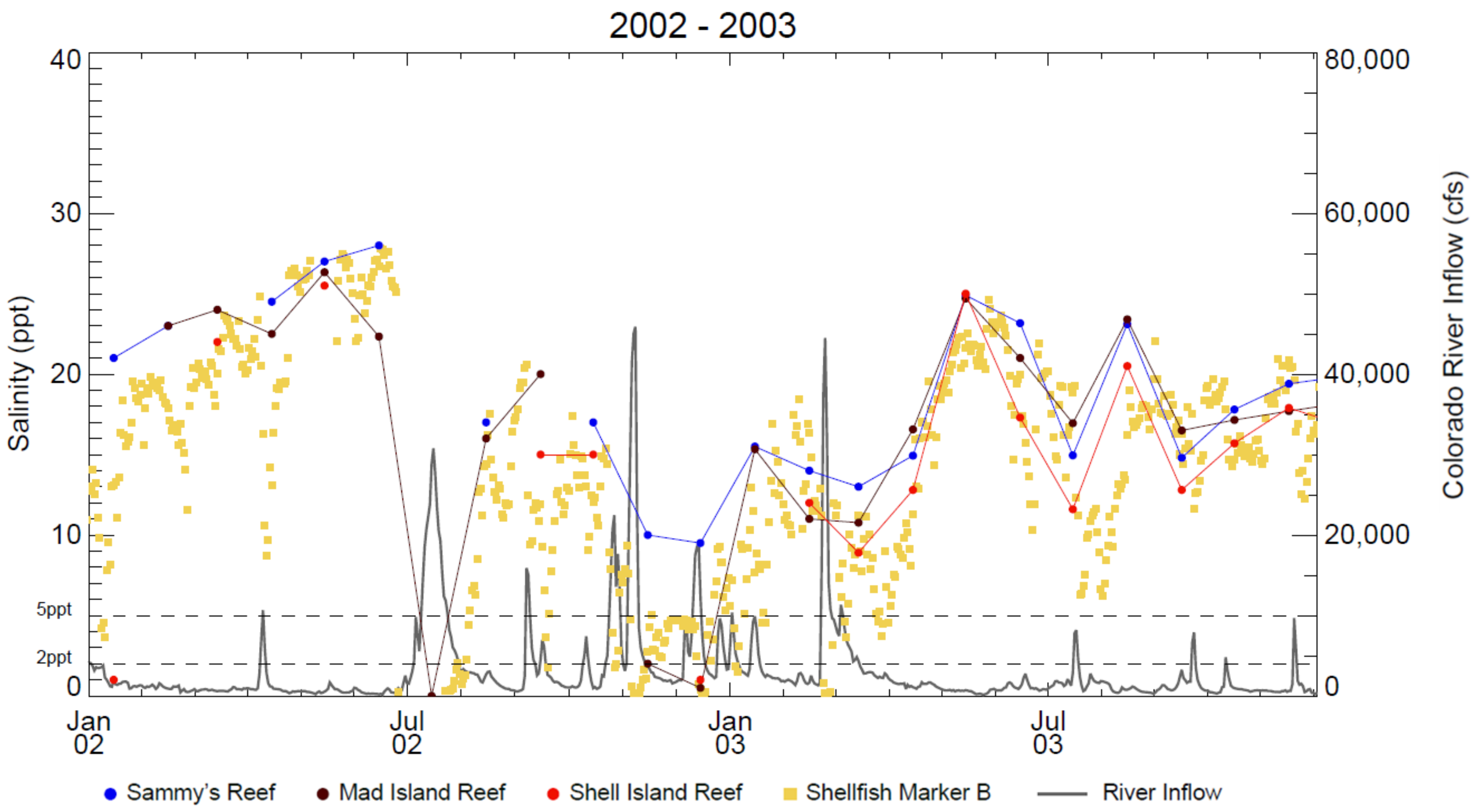
Total inflow = USGS gage flows
+ downstream modeled ungaged runoff
– downstream diversions
+ downstream return flows

- Colorado River gage is near Bay City
- Lavaca River gage is near Edna
- Garcitas Creek gage is near Inez
- This calculation of total inflow is consistent with the location where environmental flows standards are evaluated according to TCEQ definitions

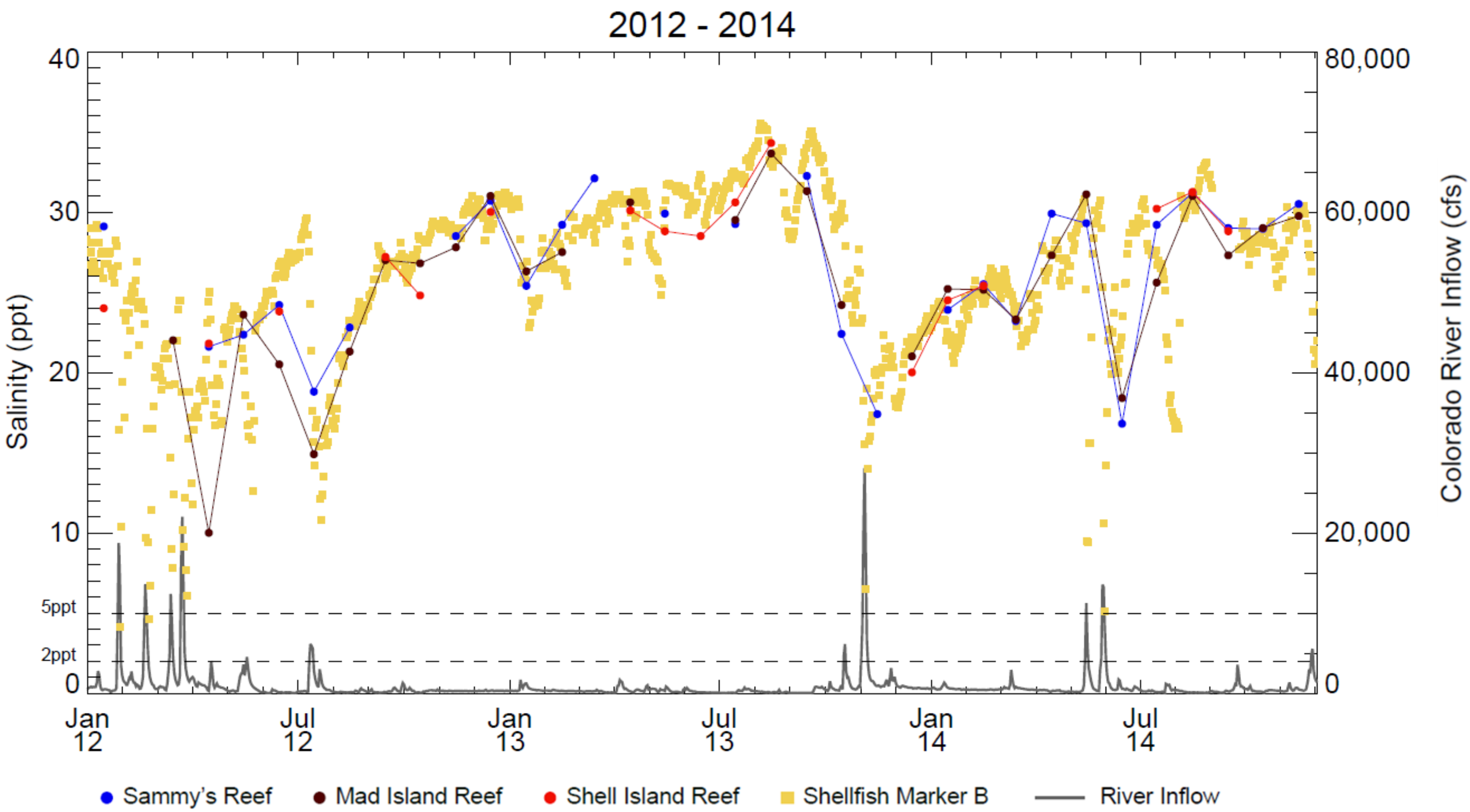
Annual Inflows Since 1977



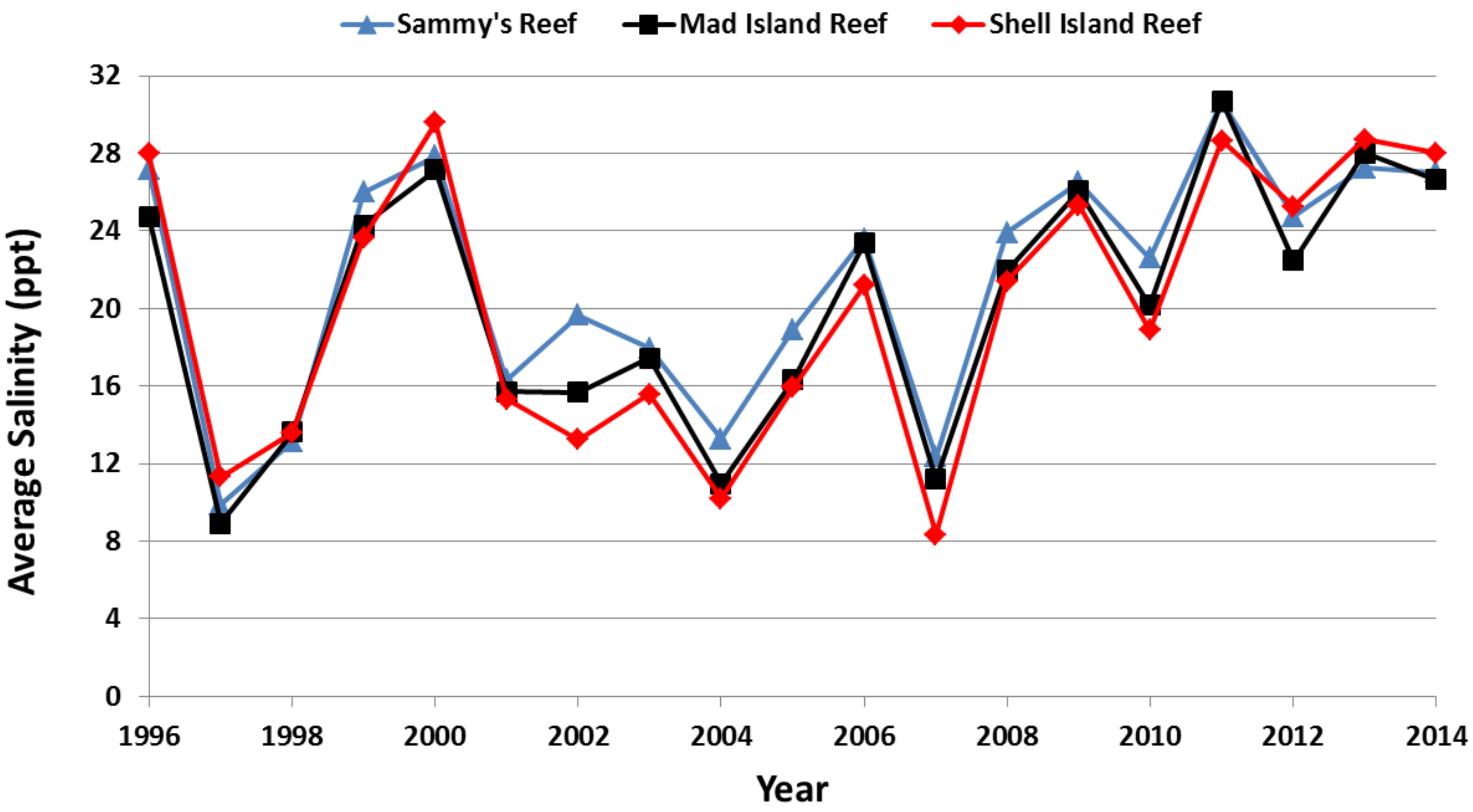
Inflows and Salinity During "Average" Years



Inflows and Salinity in Recent Past



Annual Average Salinity Since 1996



Oysters and Dermo

Oyster Ecology

- Sessile (don't move as adults)
- Euryhaline (wide range in salinity)
  - Tolerate averages from 5 to >30 parts per thousand (ppt)
  - Optimal for adults is 10 to 15 ppt
  - Optimal for spawning (at >25°C) is ±20 ppt
- Reefs exist under varying conditions throughout a bay
  - Some reefs typically have water that is more fresh than optimal and provide best conditions during drought
  - Many reefs establish in locations with optimal conditions
  - Some reefs are on saline end of optimal and provide best conditions during wet periods

Dermo Ecology

- *Perkinsus marinus*, a microscopic oyster parasite
  - Pervasive in Gulf estuaries
  - Growth increases at high temperature and salinity
  - Once oyster is infected, it never loses Dermo
    - But oyster can outgrow Dermo (for a time)
- Estimated that 50% of market-sized oyster mortality is due to Dermo

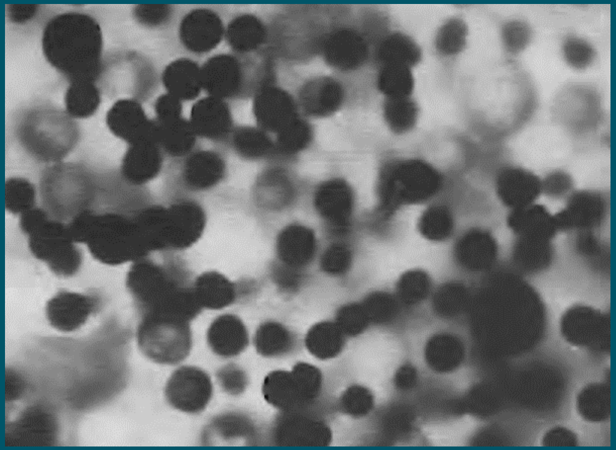


Image: Bushek et al. 1994

DERMO

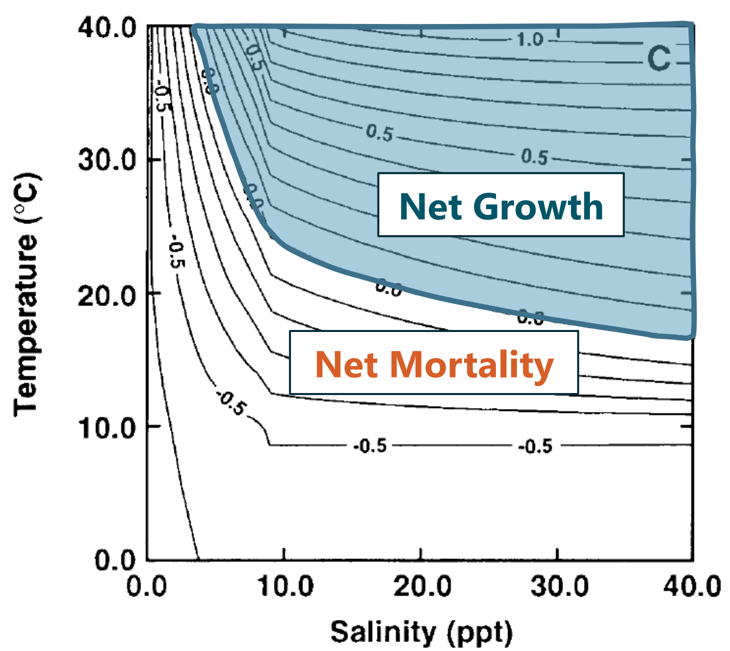


Figure adapted from Hofmann et al. 1995

Dermo Measurements

- Infection is rated using Mackin Scale
  - Scale: Uninfected (0) to Heavily Infected (5)
  - Weighted Prevalence (WP): Term used for summary metric for a group of oysters (i.e., the average Mackin score)

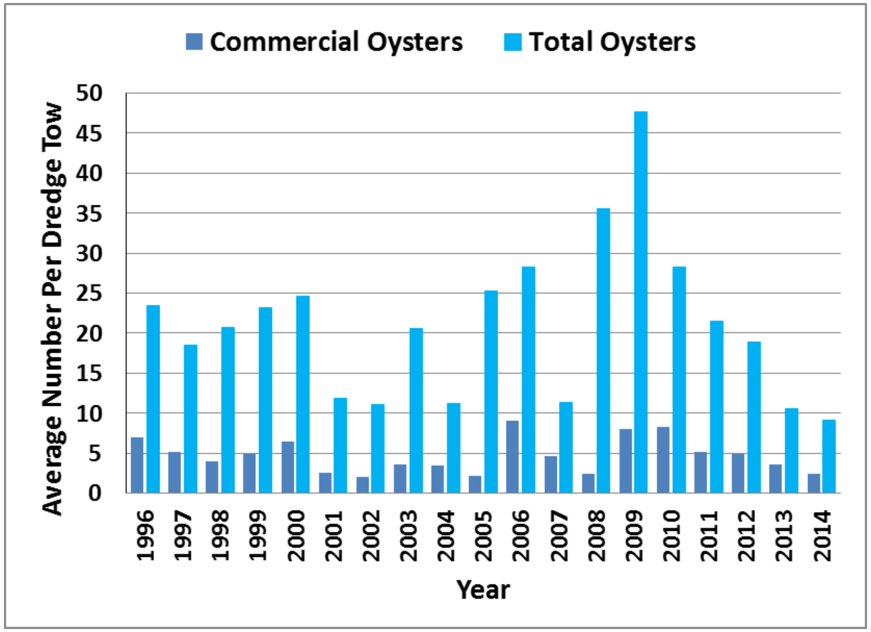
$$WP = \frac{\sum Mackin\ scores}{Number\ of\ oysters\ tested}$$

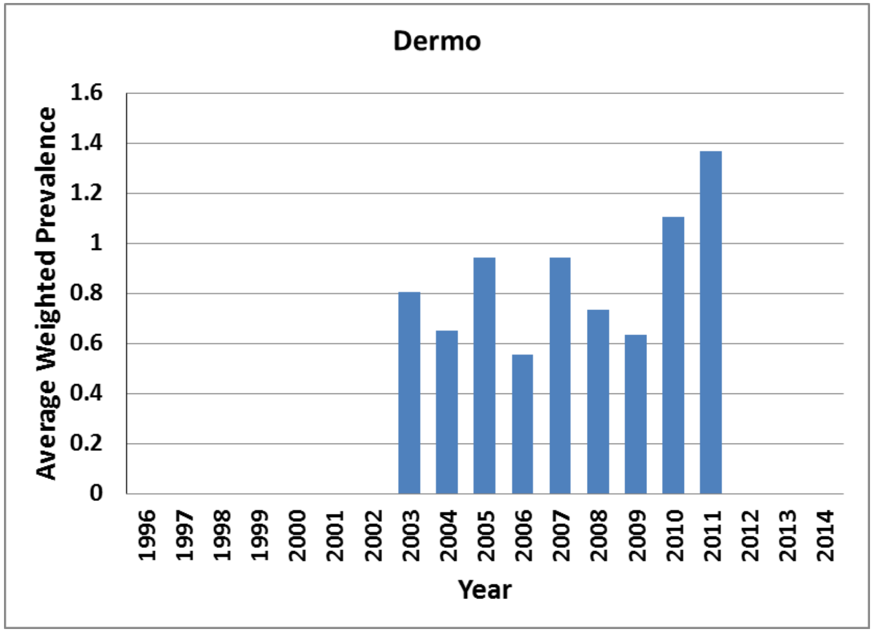
- Example using five oysters
  - Mackin score of first four oysters are each 0 and fifth oyster is a 5; hence, WP equals 1

Dermo Measurements (cont.)

- Maximum monthly average (at any location) for Matagorda-Lavaca Bays (ML Bays) is 2.9 from Mad Island, September 2010
- Points of reference
  - Mackin 1962: "[WP] of 2.00 contains an intense epidemic, and more than half of the population may be in advanced stages of disease, with all of the individuals infected."
  - Bushek 2012: "Relatively high [annual] mortality (≥25%) occurred where median [WP] routinely exceeded 2.0."

Matagorda/Lavaca Bay-Wide Trends





- Oysters increase following 2007 (a wet year)
- Oysters decline in most recent drought
- Dermo patterns are the reverse of oysters

MBHE 2008

- Comprehensive analysis of oysters and Dermo across multiple bays using data through 2007
- Dermo results more statistically significant than oyster results
- Identified as drivers of Dermo:
  - 2-year average salinity: increasing salinity increases Dermo
  - 2-year spring temperature: increasing temperature reduces Dermo
  - 3-month temperature: increasing temperature increases Dermo

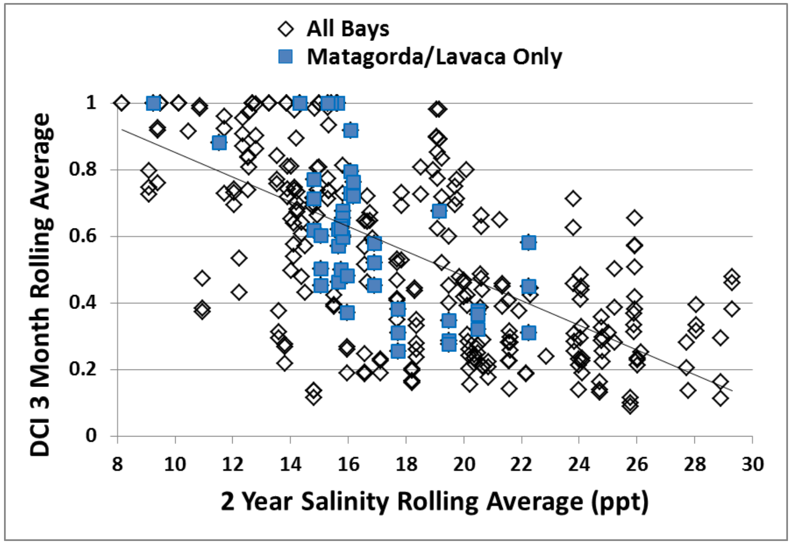
MBHE Study Converted WP into Dermo Condition Index

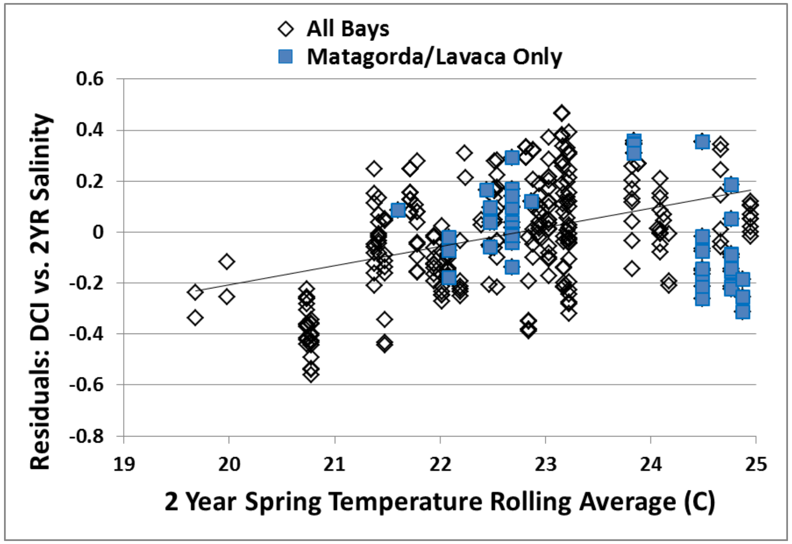
- Convert WP to Dermo Condition Index (DCI)
  - Scale (similar to Habitat Suitability Index)
    - Highest Dermo in dataset = 0
    - Ideal conditions = 1 (no Dermo)
  - Log transformed for more normal data distribution

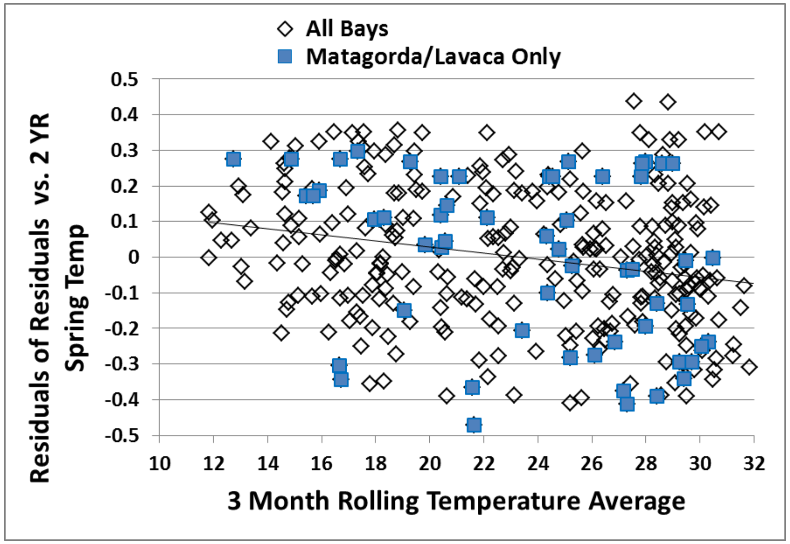
$$DCI = 1 - \frac{log_{10}(WP + 1)}{log_{10}(MaxWP + 1)}$$

  - Maximum WP (MaxWP) set to slightly above maximum of dataset (allows for higher future WP values)

MBHE Regressions on Monthly Data







Notes:

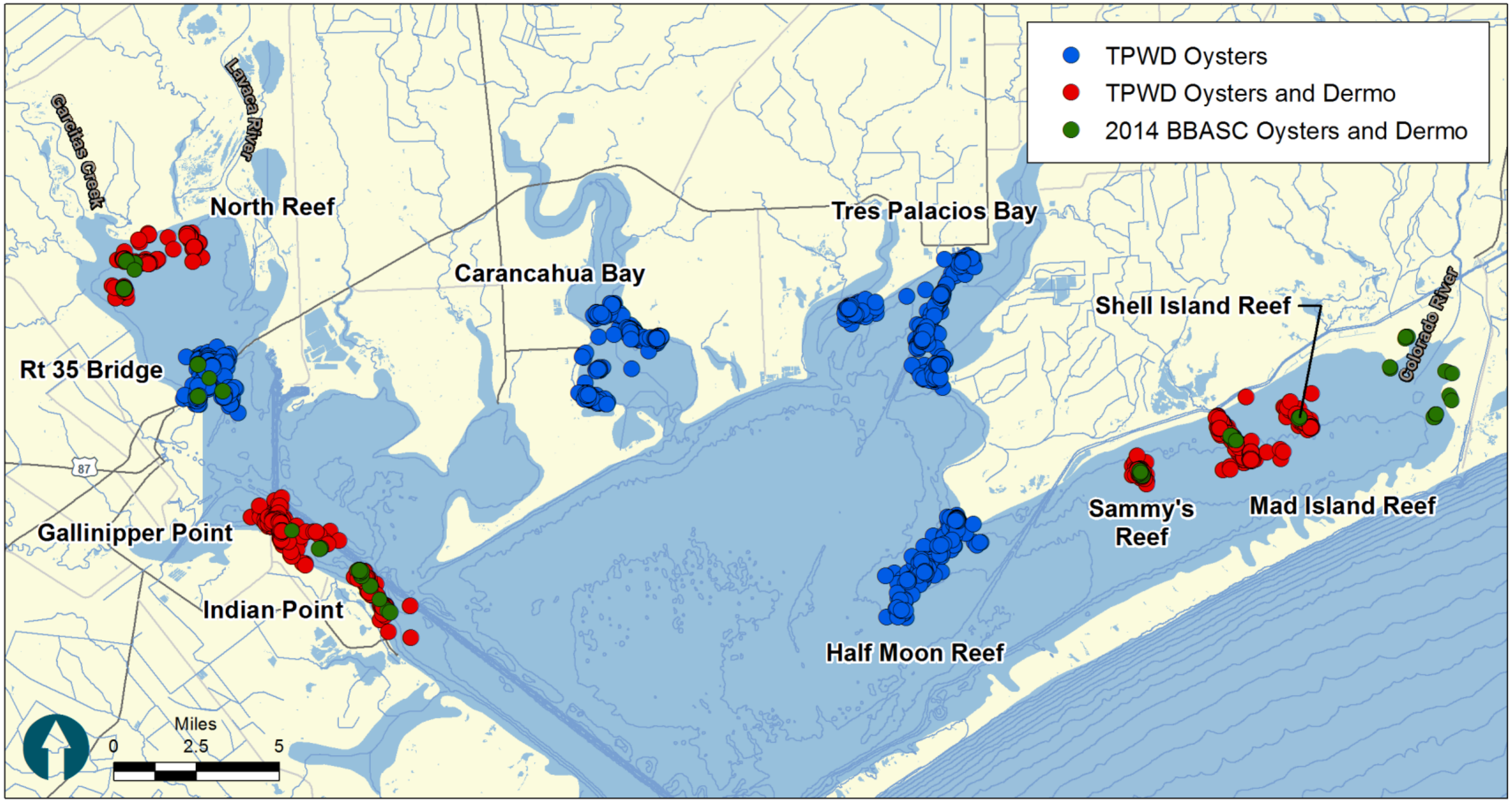
- Three-term Multiple Regression (R^2)
  $R^2 = 0.56$
- "All Bays" refers to San Antonio, Matagorda-Lavaca, and Galveston bays

Data Collected Since MBHE Study

- 2008 to 2014 TPWD oyster data
  - 60% increase in size of dataset in ML Bays
- 2008 to 2011 TPWD Dermo data
  - 250% increase in size of dataset in ML Bays
  - TPWD Dermo collection terminated in September 2011 due to budget cuts
- 2014 BBASC oyster and Dermo data
  - August/September: 139 oysters across 12 reefs
  - November: 72 oysters across 6 reefs
  - All analyzed for Dermo in Dr. Soniat's laboratory

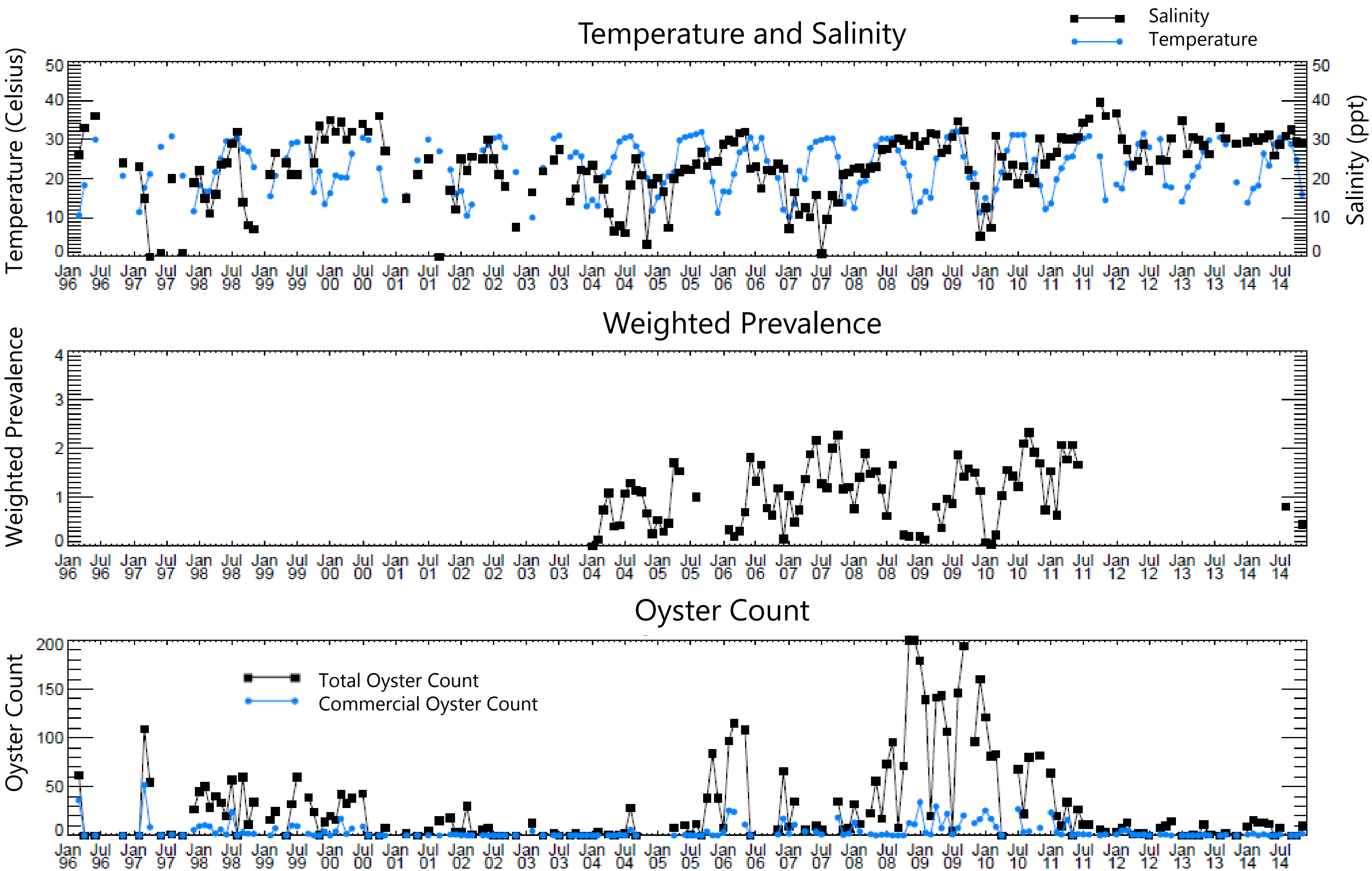
Oyster Field Collections

Map of All Data Obtained

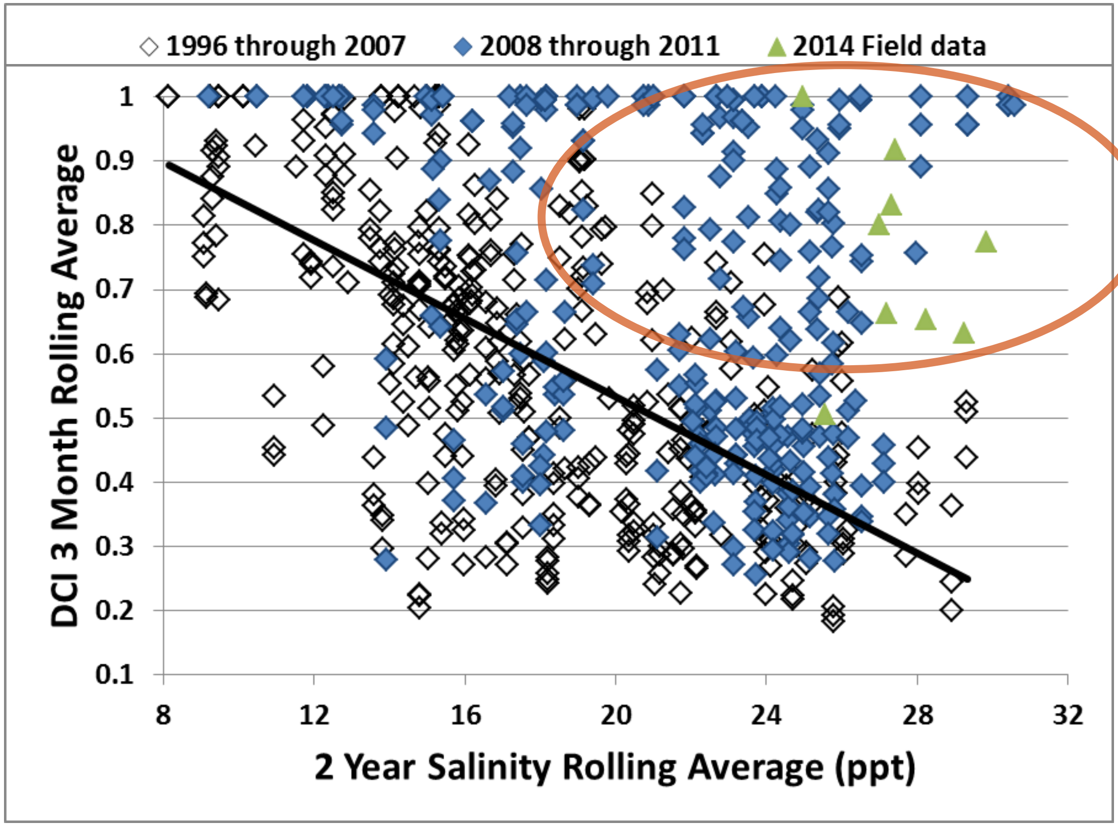


Note: Additional reefs with limited oyster data are not shown and were not included in the analyses

Time Series Example: Indian Point Reef



MBHE Regression with New Data for All Bays



Three-term R^2 = 0.20

Indicates that many new data points have lower Dermo (i.e., higher DCI) than expected based on trends from older data

Preliminary Observations

- New data substantially enhance our dataset, especially at high salinities
- New data do not closely track old predictions
- Goal is to find explanation
  - Examined ML versus San Antonio and Galveston bays
  - Examined different regression terms

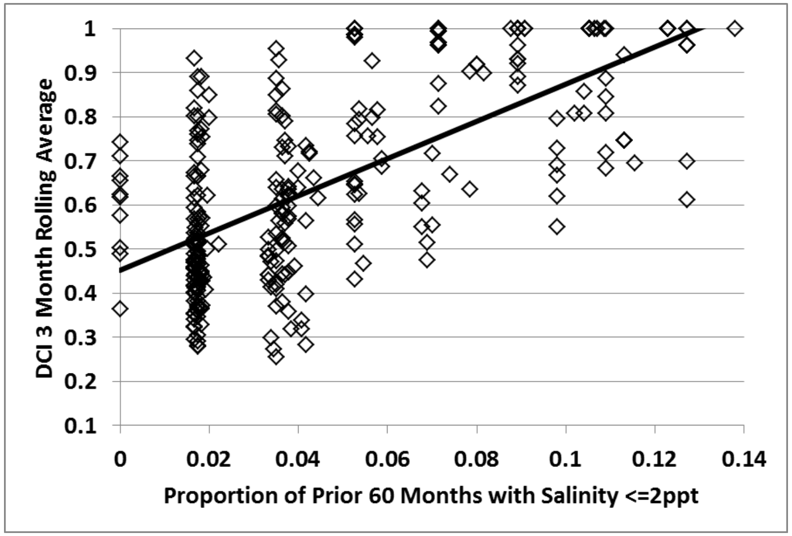
Monthly Regression Model Rebuild

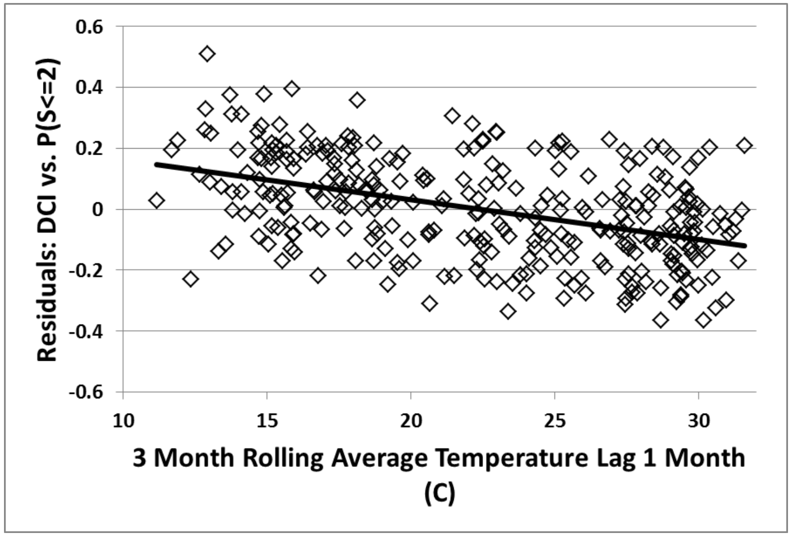
- Why: disconnect between old and new data in old model indicated need for better model terms
- ML Bays only
- New regression includes:
  - Proportion of months with salinity ≤ 2 ppt in the prior 5 years: increasing freshet frequency decreases Dermo
  - 3 month temperature, lag 1 month: increasing temperature increases Dermo
  - 2 year average salinity, lag 1 year: increasing salinity increases Dermo
- Explains more of the variability in Dermo than old model

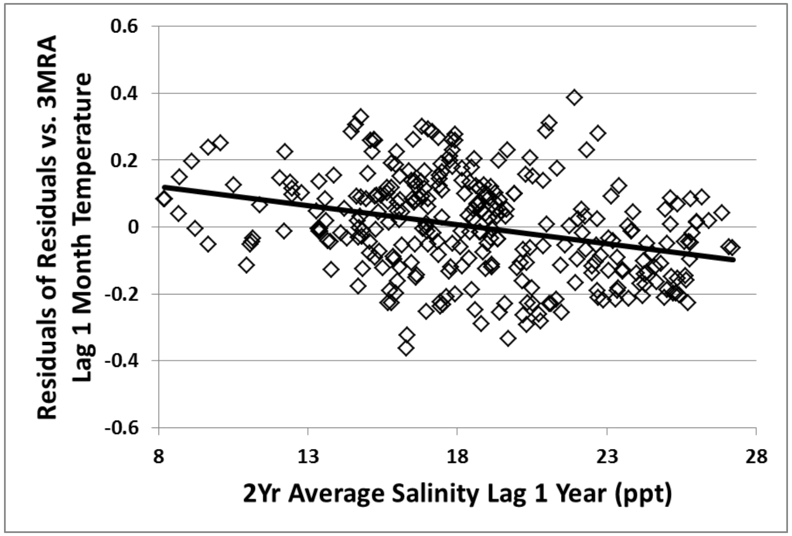
Monthly Regression Model Rebuild (cont.)

- Low-salinity event frequency term
  - Literature indicates importance of freshets
  - 2 ppt gave best results for both monthly and long-term models (1, 2, 3, 4, 5, and 10 ppt tested)
  - Longer term (5 year) average frequency worked better and more consistently across reefs
- Time lag in 2-year salinity
  - Temporal patterns of Dermo at each reef in ML Bays indicated approximately a 1 to 2 year lag between salinity and Dermo response
    - Tested several lag durations and average durations
    - 1-year lag of 2-year average provided best fit among terms tested

Monthly Regression Model Rebuild (ML Bays only)





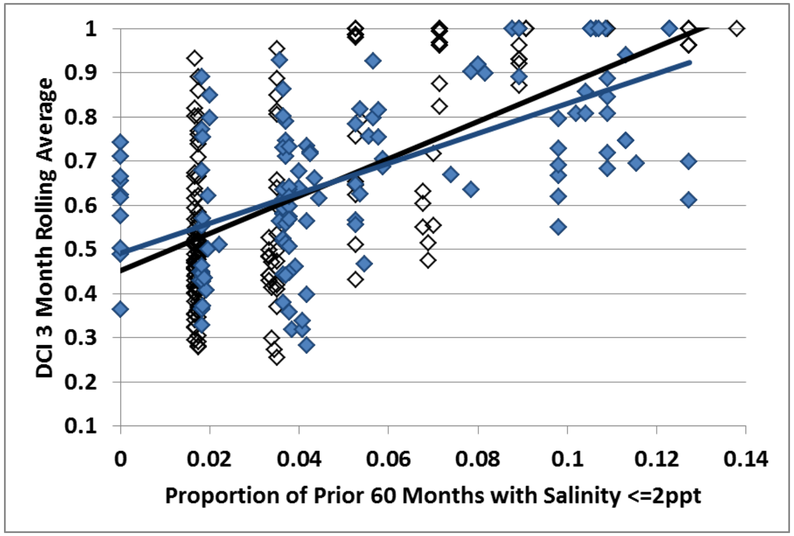


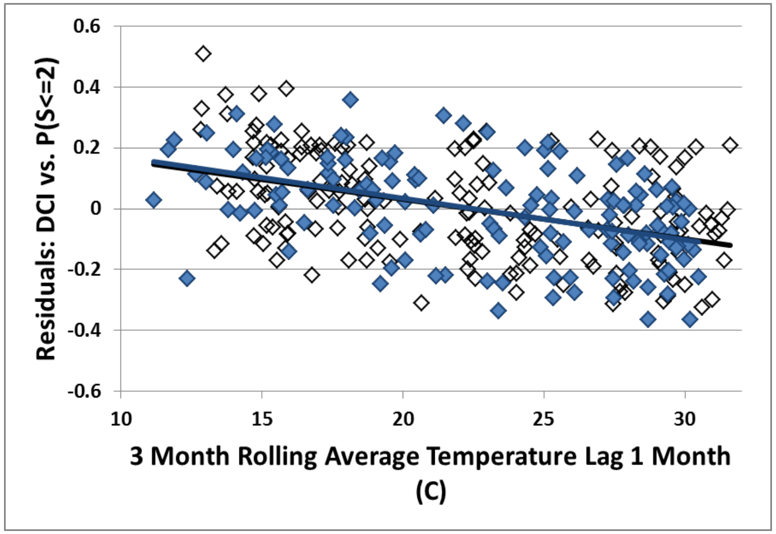
◇ **2003 through 2011**

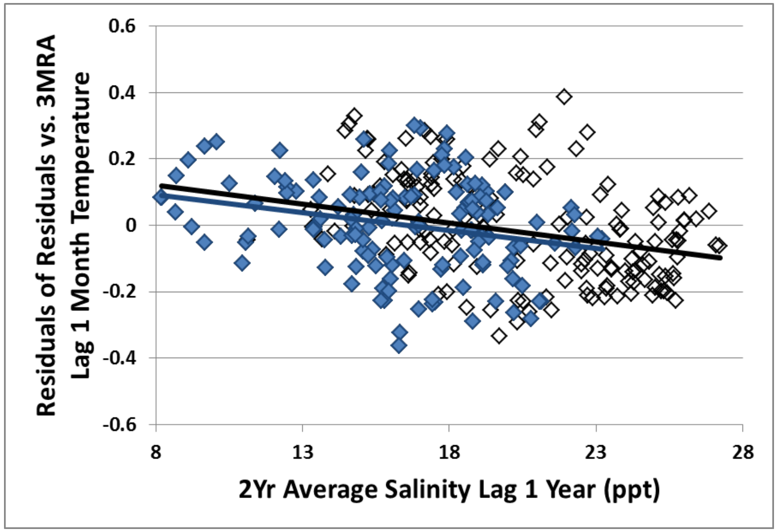
Notes:

- Three-term Multiple Regression (R^2) R^2 = 0.66 for all years

Monthly Regression Model Rebuild (ML Bays only)







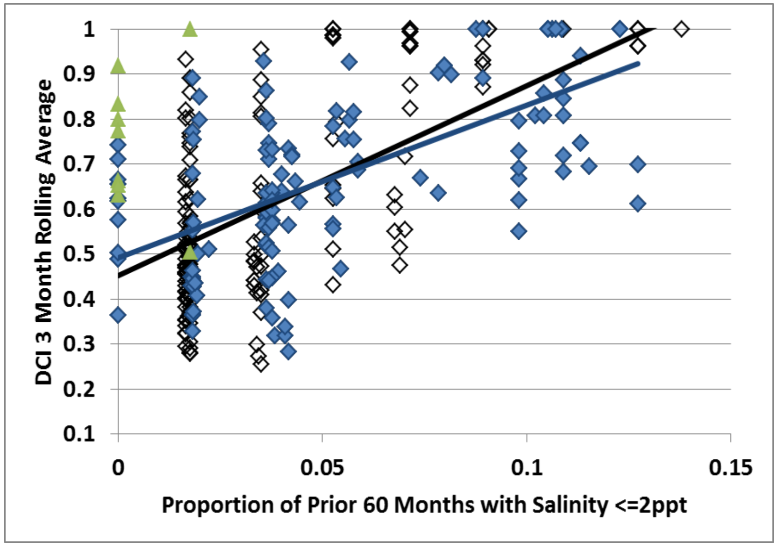
◇ **2003 through 2011**

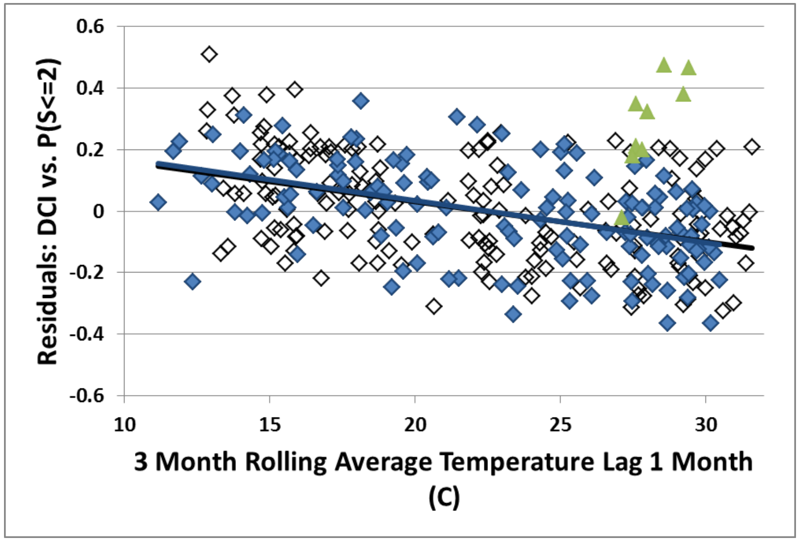
◆ **2003 through 2007**

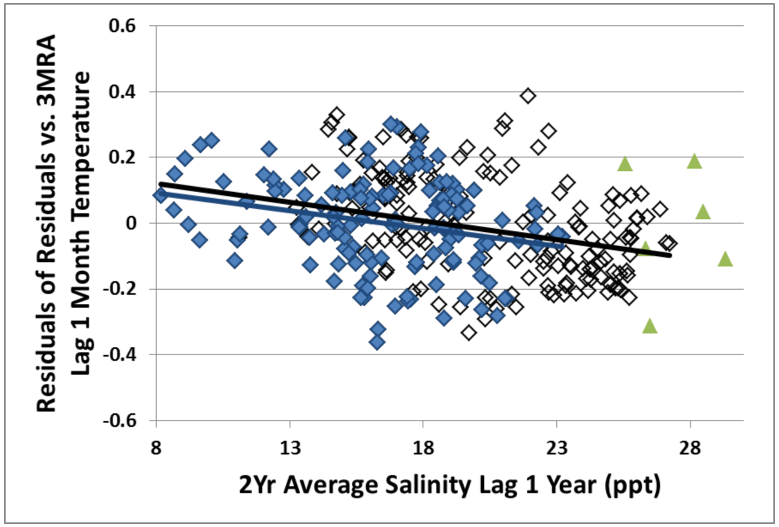
Notes:

- Three-term Multiple Regression (R^2)
  R^2 = 0.66 for all years
  R^2 = 0.65 for 2003 to 2007
- New regression has same fit for old data period as for whole data period

Monthly Regression Model Rebuild (ML Bays only)







◇ **2003 through 2011**

◆ **2003 through 2007**

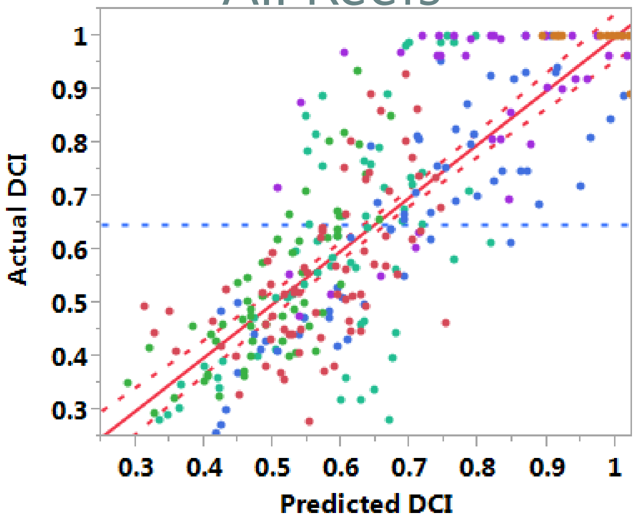
▲ **2014 Field Data**

Notes:

- Three-term Multiple Regression (R^2)
  R^2 = 0.66 for all years
  R^2 = 0.65 for 2003 to 2007

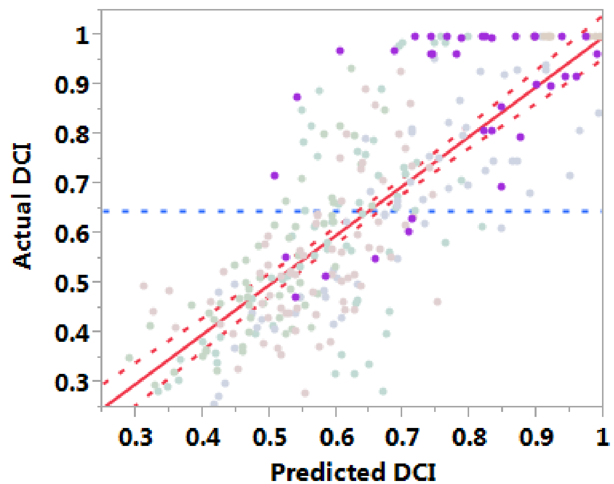
Compare DCI Response Across Reefs

All Reefs

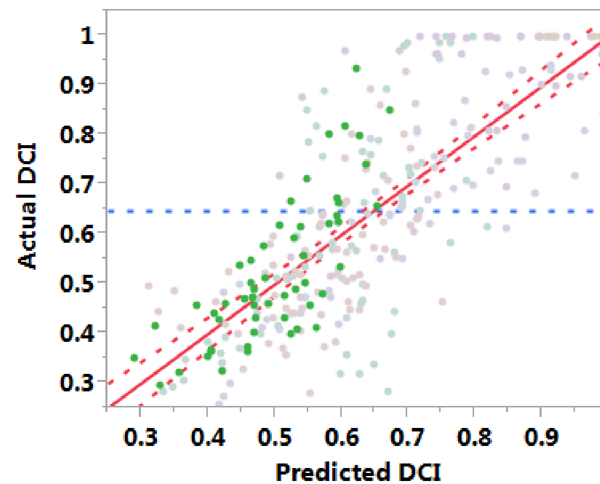


- The monthly regression model captures the range of Dermo responses at different times on different reefs
- For example:
  - Higher DCI on Shell Reef, which is relatively fresh
  - Lower DCI on Indian Point Reef, which is relatively salty

Shell



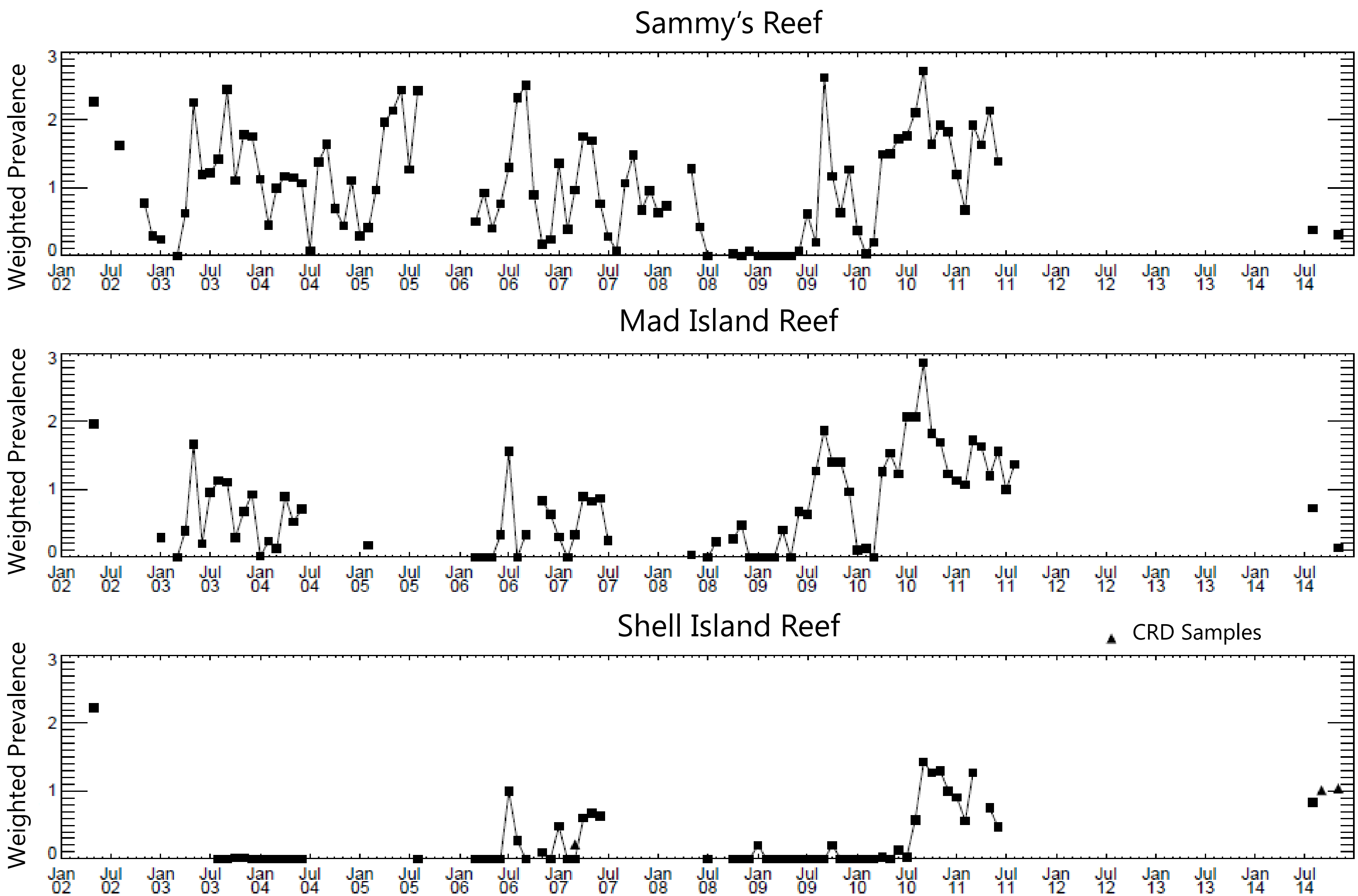
Indian Point



Expanded Efforts

- Examined Eastern Arm of Matagorda Bay (EAMB)
- Long-term average Dermo versus salinity
- Long-term oyster counts versus salinity
- Oyster Condition Index (OCI)

EAMB


Sammy's Reef
Mad Island Reef
Shell Island Reef
CRD Samples
Weighted Prevalence
0
1
2
3
Jan 02
Jul 02
Jan 03
Jul 03
Jan 04
Jul 04
Jan 05
Jul 05
Jan 06
Jul 06
Jan 07
Jul 07
Jan 08
Jul 08
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Jul 14

Observations from EAMB

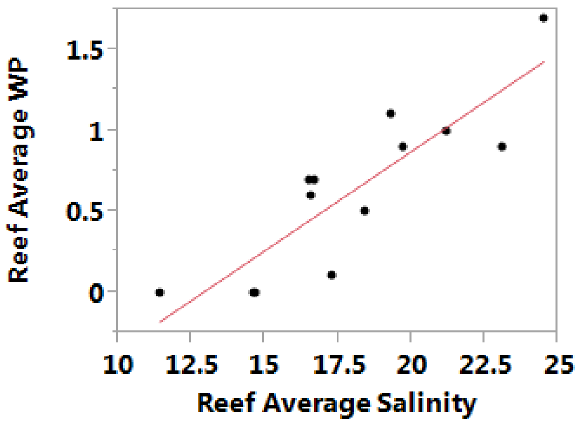
- Shell Island, Mad Island, and Sammy's Reef provide range of salinity values and responses
- Dermo is fairly consistent and high at Sammy's Reef
- Dermo has increased recently, especially at Shell Island Reef, likely due to drought
- Observations are informative, even if dataset is smaller
  - As the duration of high salinity increases into the recent drought period, Dermo increases on reefs with lower levels of Dermo, but not on Sammy's Reef
  - Lack of increase in Dermo on Sammy's Reef may be due to poor transmission of Dermo due to low density of oysters

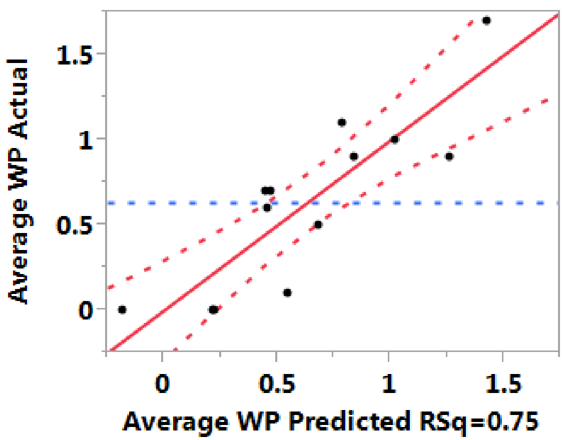
Long-Term Average Dermo Vs. Salinity

- Not evaluated in MBHE
- Simple relationship vs. salinity
  - Higher long-term (multi-year) average salinities are strongly correlated with higher Dermo on the 13 reefs that have Dermo data
- Hidden complexity
  - Actual causation of low vs. high Dermo may be also related to shorter-term events, including freshets
- Including both terms improves prediction of long-term Dermo average WP at each reef

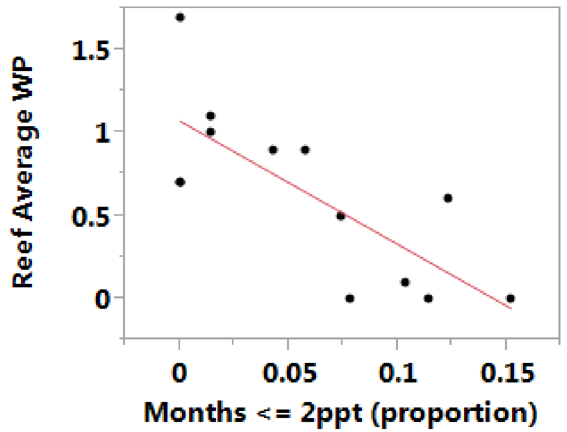
Long-Term Average Dermo Vs. Salinity 2004 - 2009

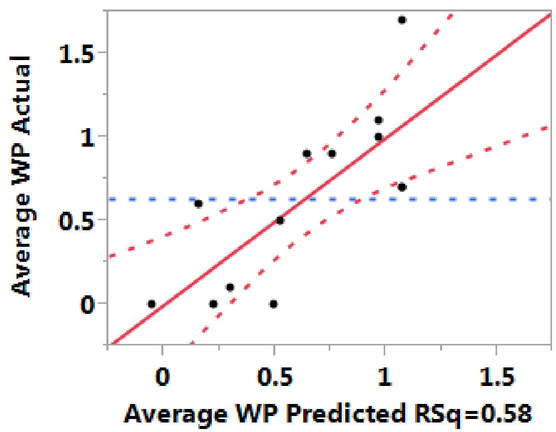
WP vs. Salinity



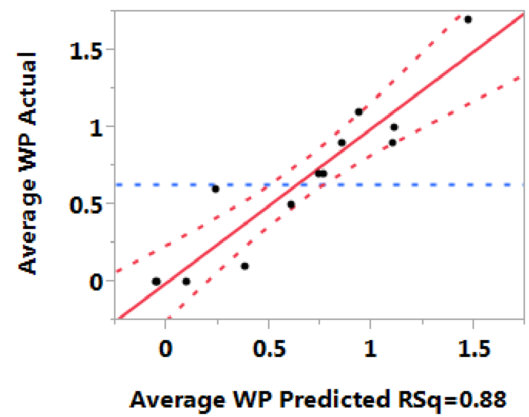


WP vs. P(months<=2ppt)



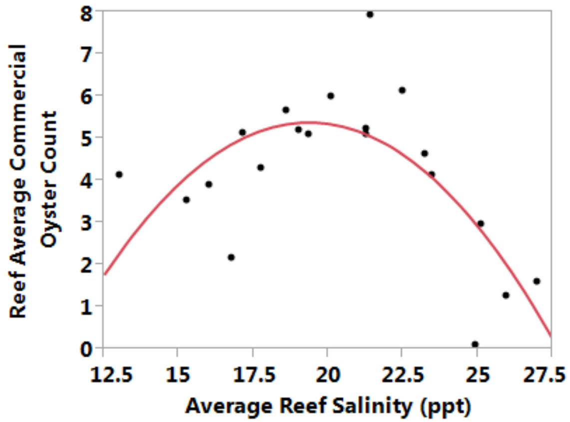


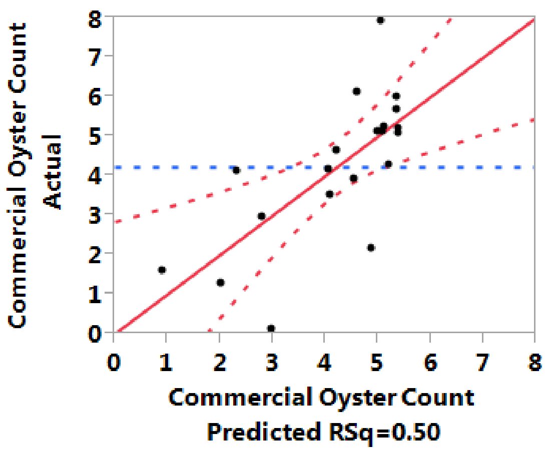
WP vs. both terms



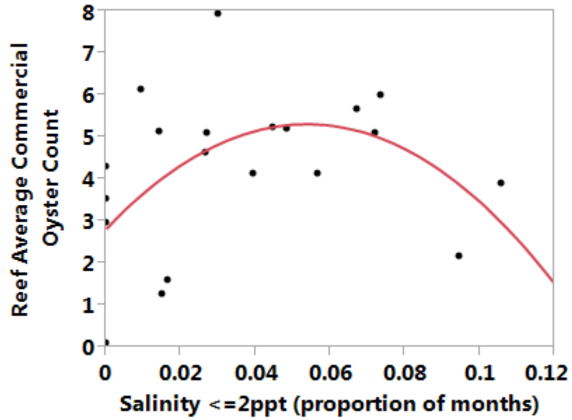
Long-Term Average Commercial Oyster Density Vs. Salinity 1996 - 2014

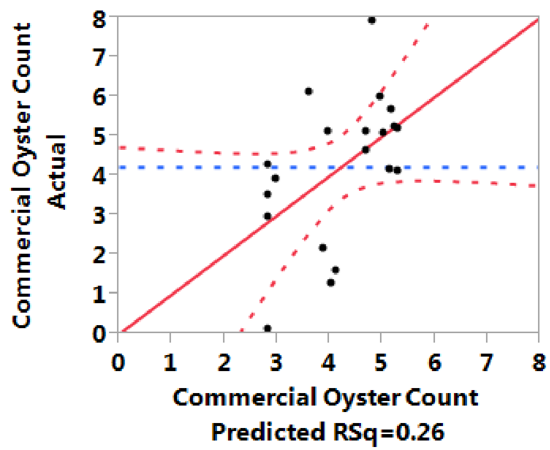
Oyster Count vs. Salinity



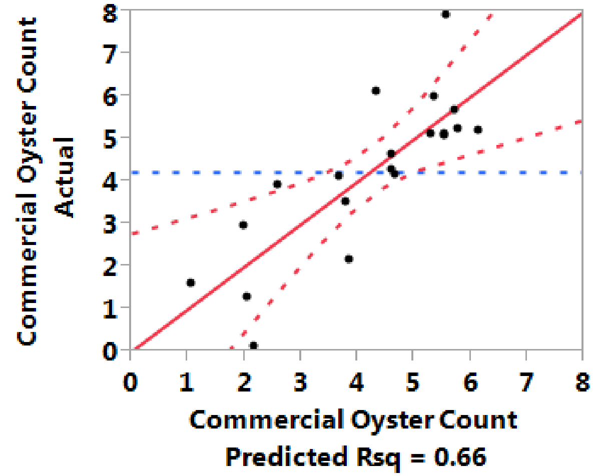


Oyster Count vs. P(months <=2ppt)





Oyster Count vs. both terms



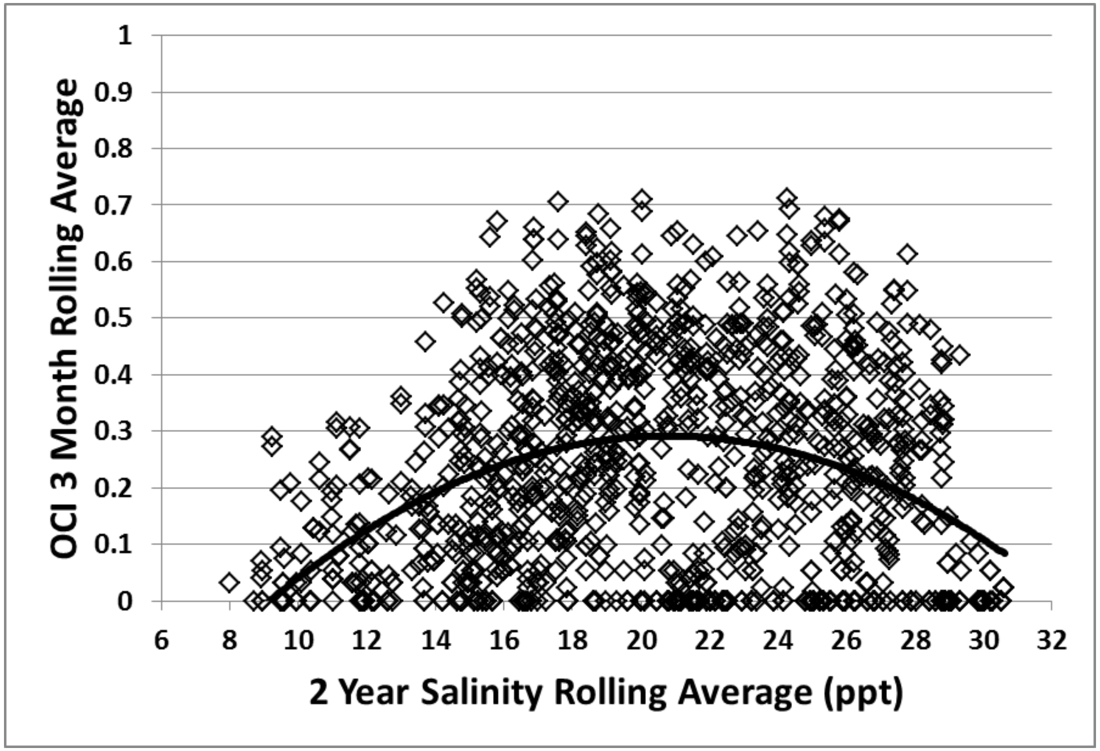
OCI

- Investigated, but not formally used, for MBHE inflow recommendations
- Similar to DCI, but based on commercial oyster count
  - Scale:
    - No commercial oysters = 0
    - Highest commercial oyster count of dataset = 1
- If successful, may be helpful in the future because of termination of Dermo collection program

OCI Monthly Regression Results

- Built monthly regression for ML Bays only
- Terms in best model for OCI did not change from MBHE effort
  - 2-year salinity: intermediate salinity is best for oysters
  - 10-year low salinity event frequency: intermediate flood frequency is best
  - 2-year Winter temperature: warm temperature during colder part of year is best

OCI Monthly Regression Results (cont.)



- 2 -Year Salinity Polynomial $R^2 = 0.11$
  - Very high month to month variability prevents a strong monthly regression model, but optimum at ~20 ppt matches optimum for long-term reef averages
- Full Multiple Regression $R^2 = 0.33$

Preliminary Conclusions

- Overall relationship between Dermo and salinity remains unchanged
  - Details of relationship between Dermo and salinity have shifted with new data
    - Freshets identified as important
    - Lag terms identified as important
- Long-term salinity matters
  - Higher salinity promotes Dermo
- Frequency of freshets matters
- OCI regression has low explanatory power, but is consistent with literature

Marsh Productivity

Biological Field Studies

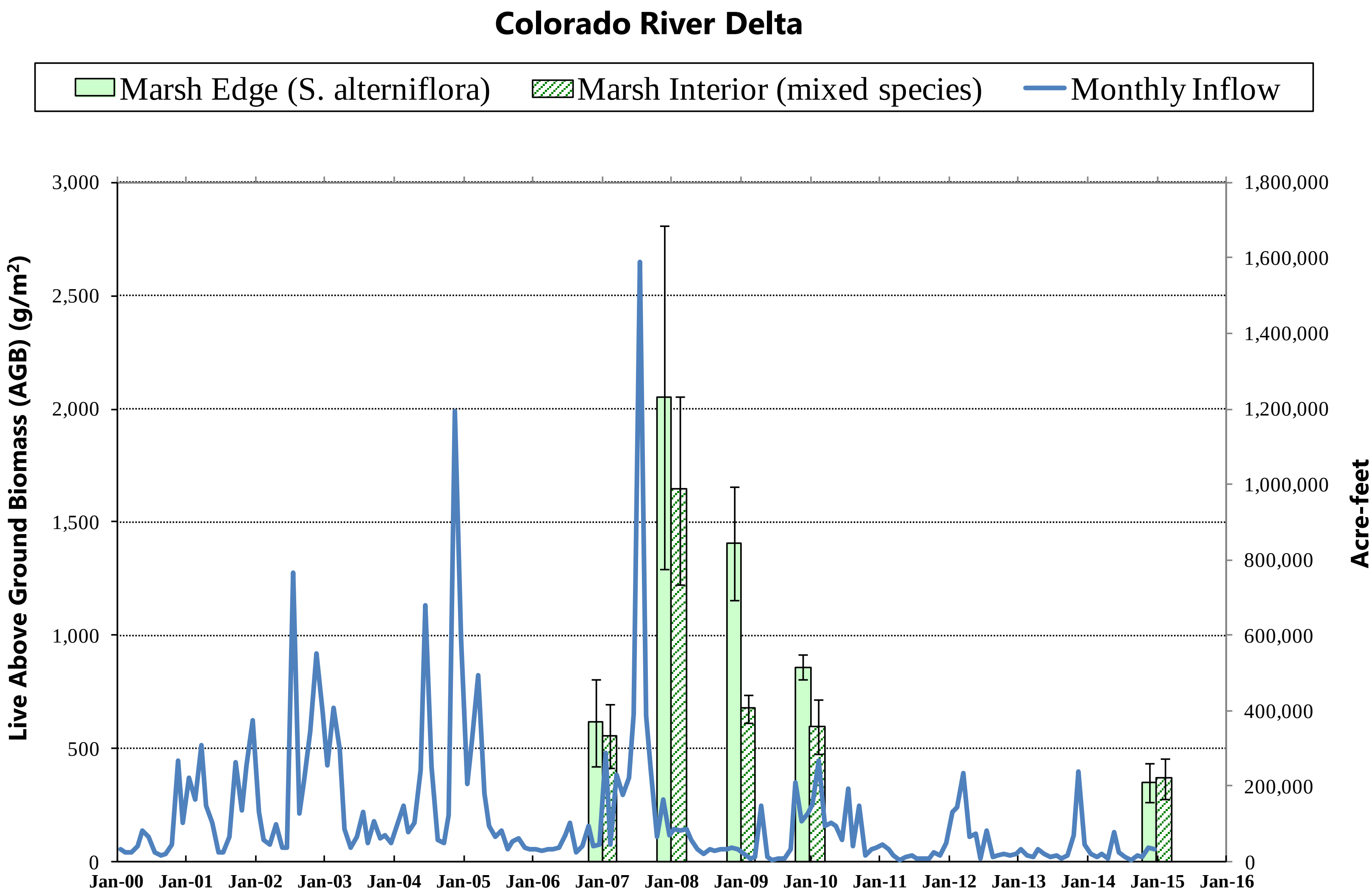
- Field investigations conducted Fall 2014
  - Colorado River Delta (CRD) – West Matagorda Bay
  - Lavaca River Delta (LRD) – Lavaca Bay
- Field surveys
  - Oyster surveys and collection
  - Marsh Vegetation sampling
  - Throw trap biological sampling
  - *Rangia* clam surveys

Marsh Productivity Sampling LRD

Marsh Productivity Sampling CRD

Marsh Vegetation Sampling (Marsh Interior)

Marsh Vegetation Preliminary Analysis



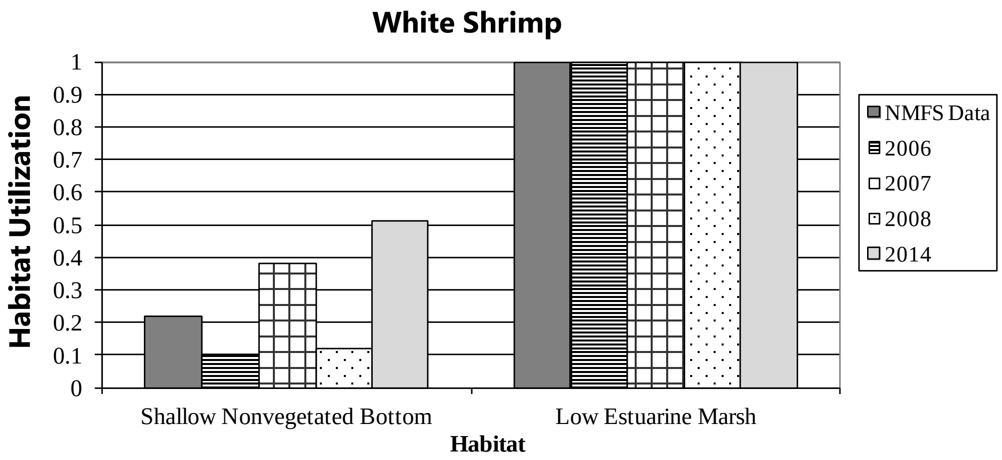
Throw Trap

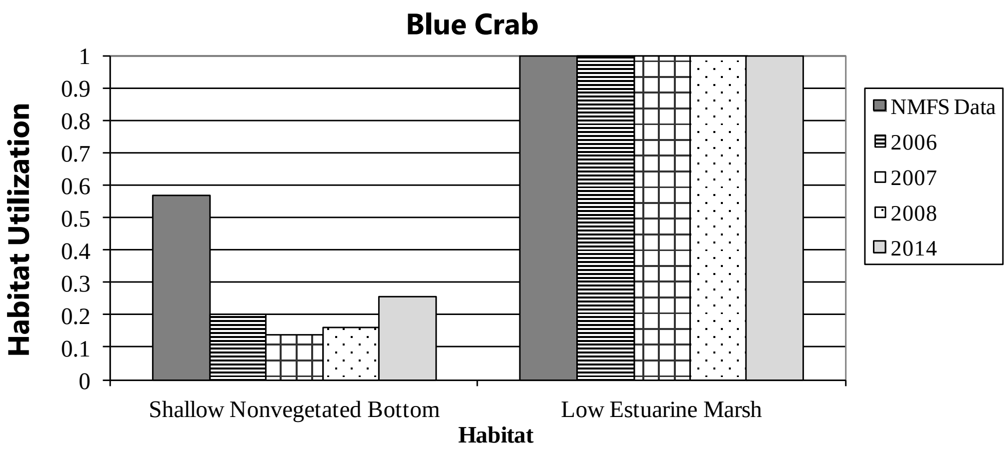
Throw Trap Biological Sampling

Throw Trap Preliminary Analysis

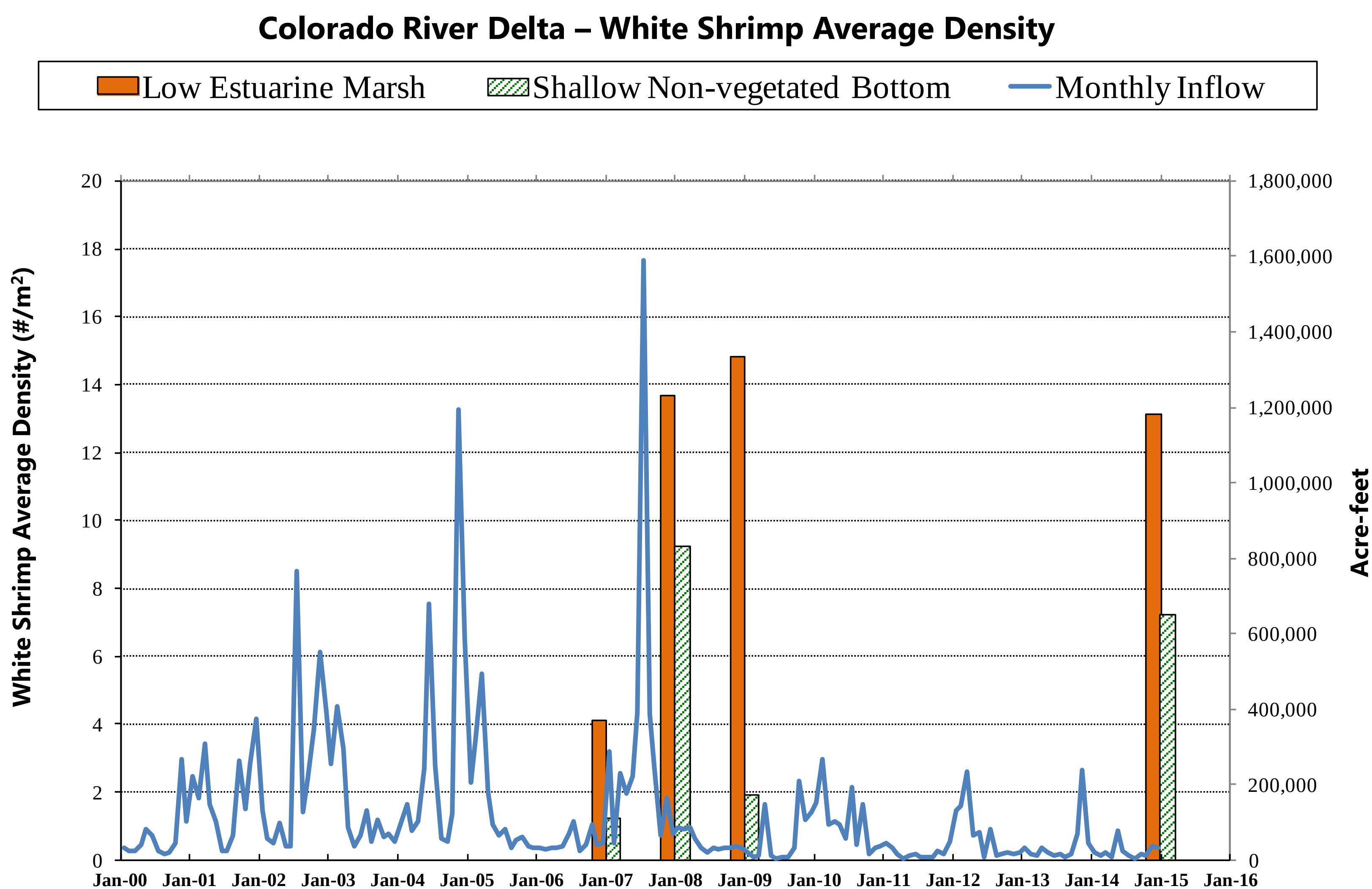
- 2014 collections
  - LRD and CRD
  - Over 5,100 individuals representing 33 species
- MBHE target species – time in bay
  - White shrimp
  - Blue crab
- Added 2008 CRD data collected since MBHE
- Preliminary findings
  - Habitat utilization consistent with historical dataset
  - Evaluation of density response trends in progress

Throw Trap Preliminary Analysis: CRD

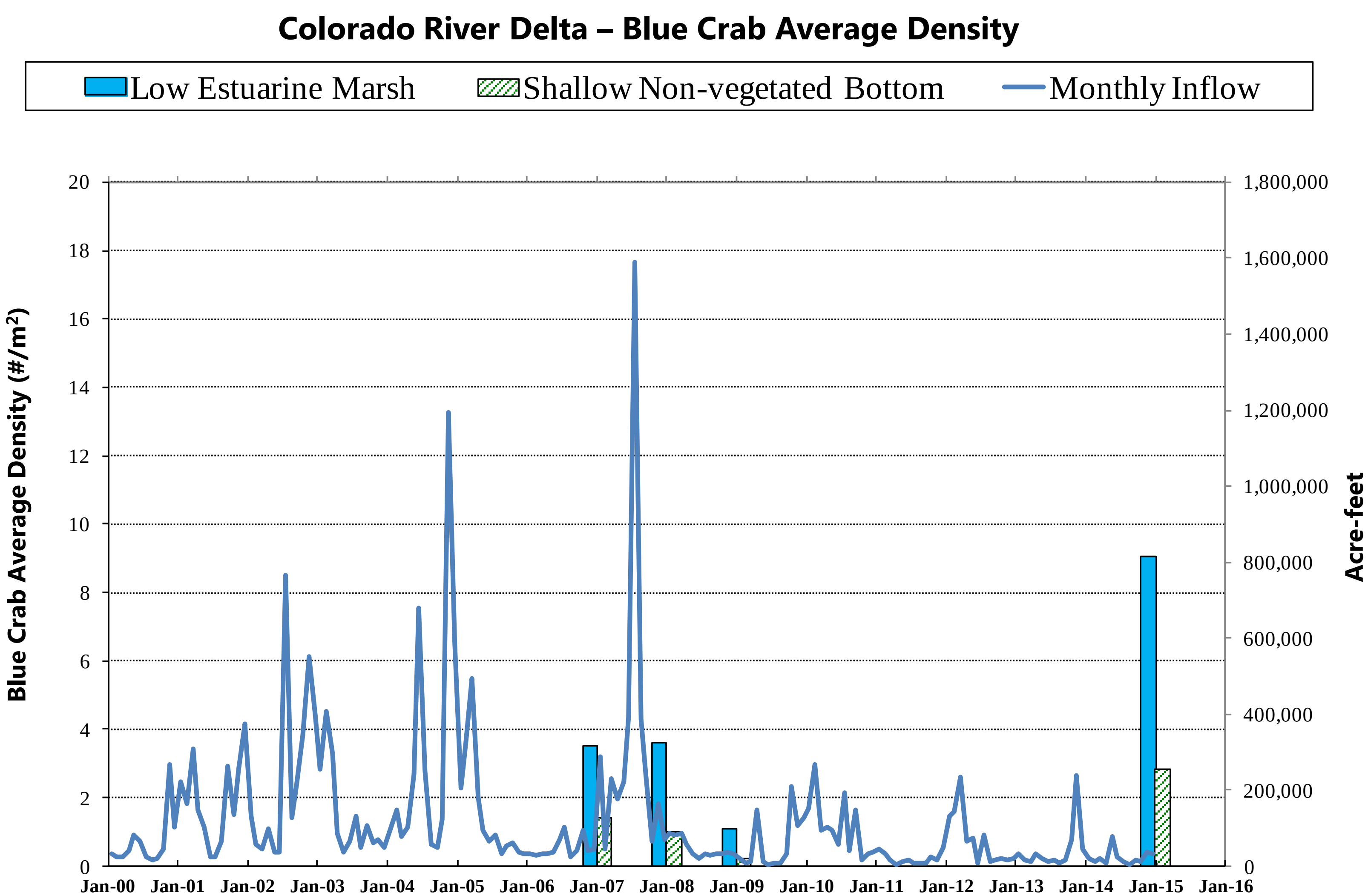




Throw Trap Preliminary Analysis: CRD (cont.)



Throw Trap Preliminary Analysis: CRD (cont.)



Biological Data Preliminary Summary

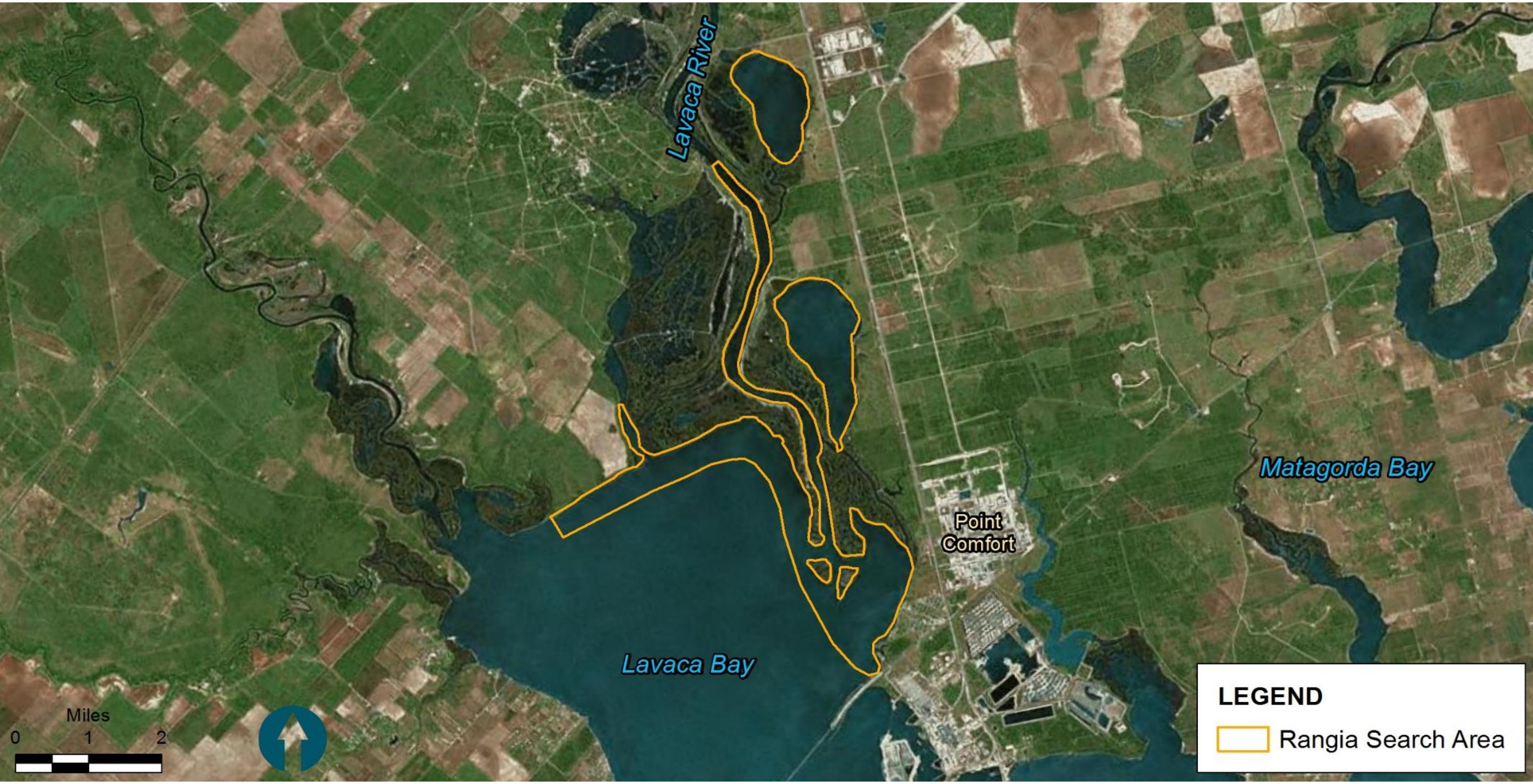
- 2014 marsh and throw trap collections
  - Snapshot in time
  - Limited sampling window in bay provides only restricted analysis for target organisms
- Marsh vegetation exhibits apparent trend with inflow
  - Less biomass produced with reduced inflows and high salinities as predicted by original MBHE analysis
  - Supports environmental flow recommendations framework of varying tiers and achievement guidelines

Biological Data Preliminary Summary (cont.)

- Encouraging that habitat utilization is consistent with historical dataset
  - Means low estuarine marsh habitat still supported juvenile organisms in 2014
  - Supports “Threshold” concept of eFlow recommendations
- Preliminary results suggest no density response trends for target species
  - Density alone does not support predicted reductions in target species (white shrimp and blue crab) juvenile organisms under high salinity conditions
  - Increased density might represent clumping
  - “Health” index for biological assemblage data under further investigation

Rangia Clams

Lavaca River *Rangia* Investigation



Colorado River *Rangia* Investigation

Rangia Sampling Summary

- Areas of investigation
  - LRD
  - CRD
- Methods of investigation
  - Substrate probing
  - Dredge tows
- Results
  - No *Rangia*, alive or dead, were found within these survey areas

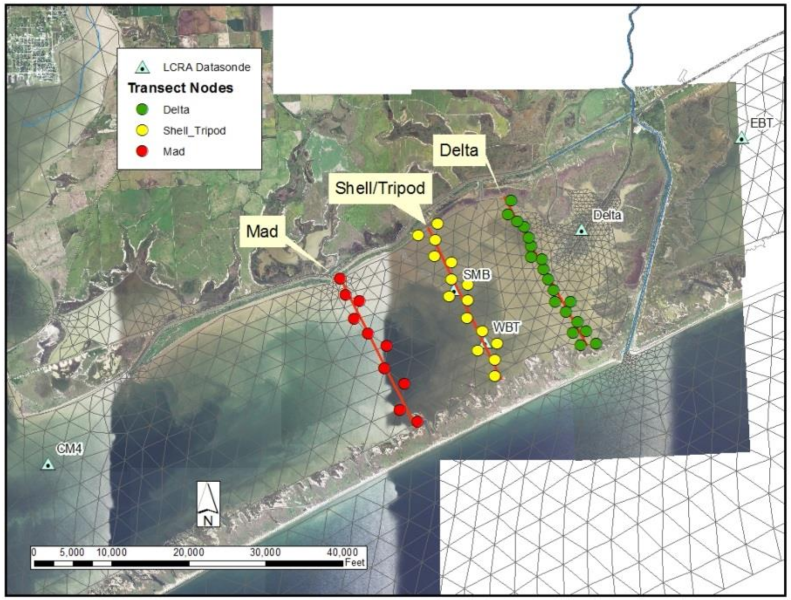
Salinity Modeling

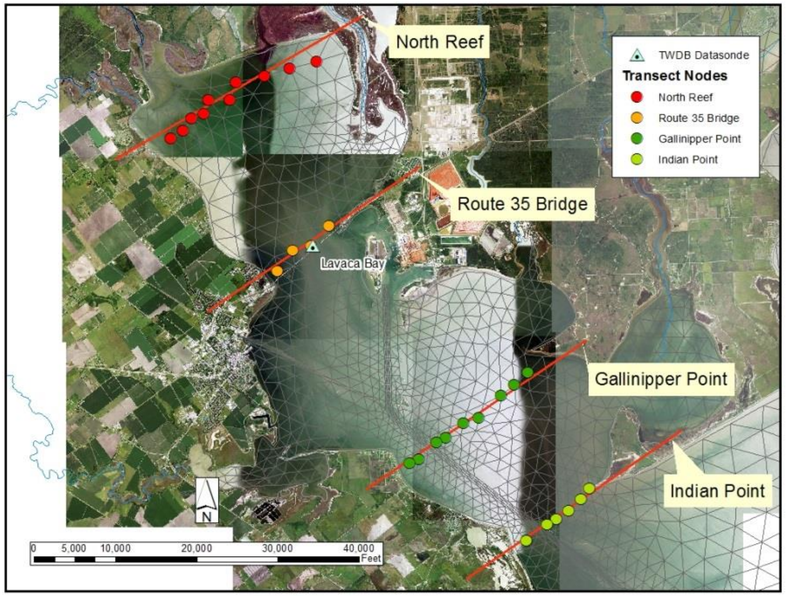
Translation of Salinity Targets to Inflows

- MBHE team selected ecological conditions (i.e., refuge, poor, fair, good, selected) and identified corresponding target salinity values based on ecological data
- MBHE team used salinity model to help translate salinity targets at specific locations back to inflow recommendations

Salinity Modeling and Predictive Inflow Regressions

- Salinity model is used to predict a daily time-series of salinity at points throughout the estuary
  - Model does not directly identify what flows are needed to produce a desired salinity value
- Regression relationships are developed to provide a practical approach for relating salinity to inflows





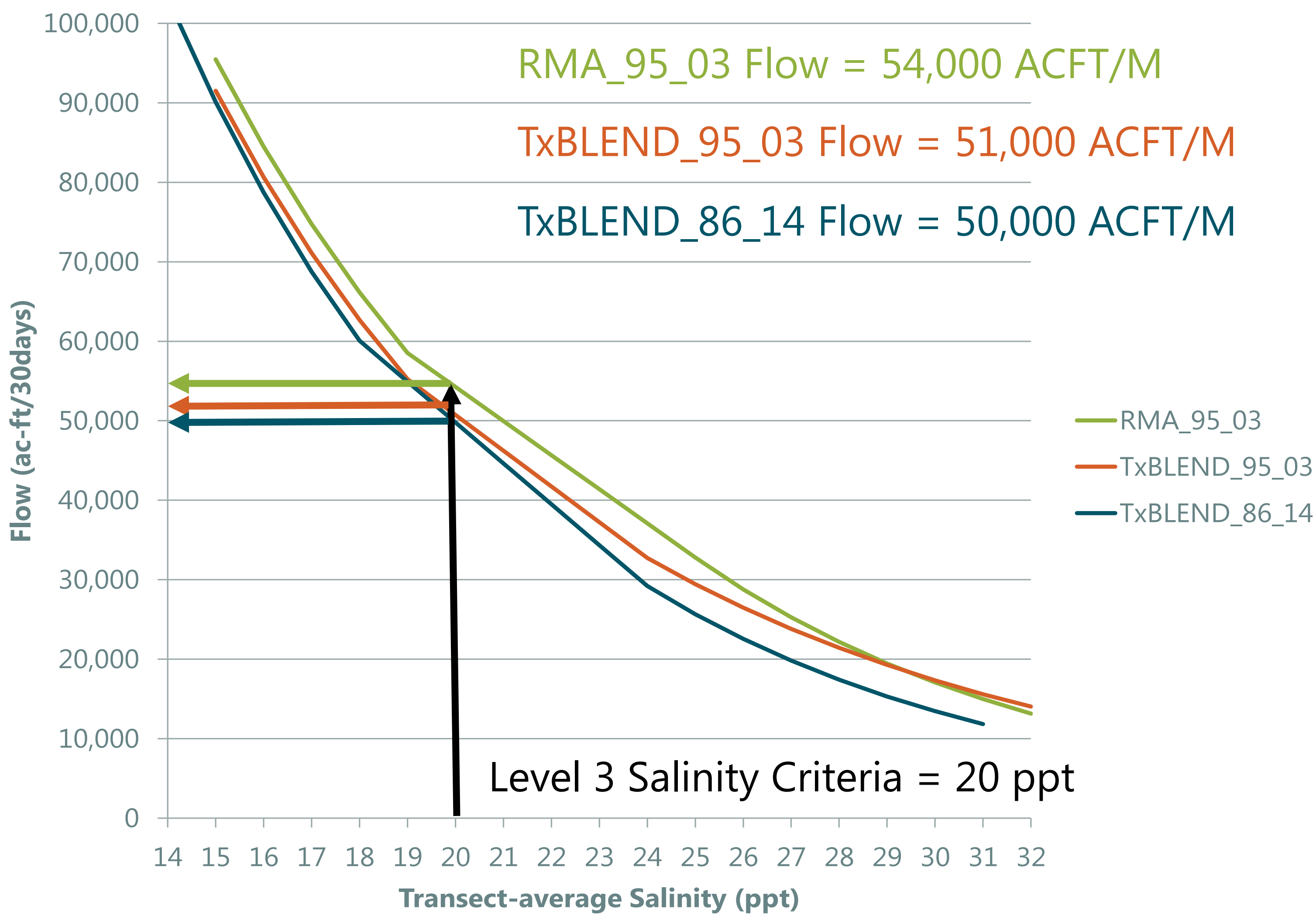
Switching from RMA to TxBLEND

- MBHE used RMA model
- Advantages of RMA
  - Handle wetting and drying in marsh areas
  - Potential for coupling to other RMA models to evaluate other parameters
- Disadvantages of RMA (specifically as developed for MBHE)
  - Somewhat unstable (often crashed) and long computer simulation time (weeks)
  - Not maintained or updated with new data (thus, period of record is limited to July 1995 to December 2003)
- Advantages provided by RMA were not factors in flow recommendation; disadvantages of continuing to use RMA were significant compared to TxBLEND model (maintained by TWDB)

Updating TxBLEND Model Period of Record

- Working with TWDB to update meteorologic and hydrologic inputs to TxBLEND from 2009 to 2013 (preliminary 2014)
- Metrologic inputs include winds, tides, evaporation, precipitation, and off-shore salinity boundary
- Hydrologic inputs include total daily inflows for 15 locations.

Total daily inflow = USGS gage flows
+ modeled ungaged runoff
– diversions
+ return flows



Results at CRD transect generated from TxBLEND are generally comparable to those based on RMA

Next Steps

Next Steps

- Finish analyzing data
- Determine if results indicate salinity ranges are corresponding to ecological conditions (i.e., refuge, poor, fair, good, and selected) should be adjusted
- Using salinity regressions, identify freshwater inflows to achieve target salinity ranges

Schedule

- Draft report due June 30
- TWDB (and BBASC) review by July 31
- Final report due August 31

Questions/Discussion

Backup Slides

Colorado Inflows and MBHE Levels